Article

Phenotypic variability in faba beans collections from the Valley Toluca-Atlacomulco, Mexico

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Abstract

This study was conducted in the spring-summer 2014 cycle in San Mateo Atenco, Mexico State, Mexico, with the objective of estimating variance and heritability components in 39 faba bean cultivars and identifying outstanding genetic material from quantitative traits and qualitative. A randomized complete block design with three replications was used. The qualitative characteristics were described according to the technical guide for the varietal description in faba bean of the national service of inspection and certification of seeds (SNICS). The results showed statistical significance ($p\leq 0.01$) among cultivars for each quantitative characteristic. Heritability in the broad sense varied from 30.7 to 99%. The highest seed yield was recorded in the collections identified as T8 (4.16 t ha^{-1}), T5 (3.9 t ha^{-1}) and T 27 (3.8 t ha^{-1}). The principal components analysis explained 65.2% of the original total variation and in this it was observed that the yield correlated positively and significantly with number of pods, pod weight and seed weight. In the cluster analysis four groups were formed, of which the third of these included the faba bean populations with the best agronomic descriptors evaluated.

Keywords: *Vicia faba* L., analysis of morphological and agronomic characters, High Valleys of Central Mexico, multivariate analysis.

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Introduction

The study of variability based on morphological and agronomic traits is a fundamental tool in the genetic improvement schemes and in the efficient conservation of germplasm (Pearce *et al*., 2000; Cordeiro *et al*., 2003). The faba bean is a partially allogamous species, which makes it more expensive and difficult to maintain the genetic identity of the cultivars (Pearce *et al*., 2000; Duc *et al*., 2010), which is why creole or native materials of time have fixed genes of interest, represent an important source of germplasm (Yahia *et al*., 2012).

For two decades there have been intensive studies on the phenotypic variability that exists in traits of agronomic interest: in the Mediterranean, Suso *et al*. (1993); Terzopoulos *et al*. (2003), in Germany and France it has found wide variability in flowering, earliness, growth habit, architecture stem, internode length, number of branches, kind of growth and stiffness of the stem (Arbaoui *et al*., 2008), in Syria has been reported wide variety pigmentation stem, size and shape of the leafs, color stain of melanin in the wing and the standard angle shape, surface, color and distribution of the pods, and in different colors in the seed, in the testa and in the *hilium* (Robertson and El-Sherbeeny, 1991), in Ethiopia the faba beans are different mainly in the size of the leaves and in the position and color of the pods.

In China, Li-juan *et al*. (1993) found that the cultivars differed basically in the size of the pod, in the number of seeds per pod and in the color of the seed. The health, size and color of the seeds are very important characteristics for Mexican farmers, and they use them to identify outstanding cultivars (Díaz *et al*., 2008; Escalante *et al*., 2012). Duc *et al*. (2010) reported nearly 38 000 faba bean accessions grouped into 37 collections, mostly from Asia, Africa and Europe. In America and particularly in Mexico, there is no reliable gene bank that protects the genetic diversity of the existing germplasm.

The genetic improvement and the generation of technology in this legume is incipient, the farmers of this region of Central Mexico are the owners of the native populations that they have selected empirically and also they are of the technological package that they use in their exploitation (Díaz *et al al*., 2008; Rojas *et al*., 2012; Orozco *et al*., 2013; Pérez *et al*., 2014).

In the previous context, the main objective of the present study was to describe 23 agronomic characters in 39 faba bean cultivars collected in the Toluca-Atlacomulco Valley, Mexico, based on the technical guide of the SNICS seed variety description (2001), for identify outstanding materials that allow its recommendation in commercial sowing, initiate new breeding programs or generate technology.

Materials and methods

Description of the study area

This work was carried out in the Spring Summer 2014 cycle in the Barrio de Guadalupe, Municipality of San Mateo Atenco, State of Mexico, Mexico, located at 99º 31’ 10’’ North latitude and 99° 34’ 05’’ West longitude, at 2 570 masl. The predominant soils are of alluvial origin and

87% of its surface are of the feozem type. The common climate is C (w_2) (w) b (i’’) g; that is, temperate sub-humid, with long summer and winter rain. Its average temperature varies from 10 to 12 °C and the precipitation ranges between 700 and 900 mm (García, 1988).

Genetic material

39 cultivars of faba bean, 35 of these were collected in the Mexiquenses Municipalities of Acambay, Jocotitlan, Calimaya, Mexicaltzingo, Santa Cruz Atizapan, Santiago Tianguistenco, Almoloya del Río, Toluca, Zinacantepec, Metepec, Lerma and San Felipe del Progreso were considered. The other four were formed by the Agricultural, Aquaculture and Forestry Research and Training Institute of the State of Mexico (ICAMEX). In the Table 1 shows the identification code, the place of collection, the characteristics of the seeds, the altitude and the geographic coordinates of the municipalities where they were collected.

Experimental design and size of the plot

The 39 cultivars were established in the field in a randomized complete block design with three replications. The plot consisted of three rows of 4 x 0.8 m and the central furrow was the useful plot (3.2 m^2).

Agronomic management

The preparation of the land was mechanical. Planting took place on April 20, 2014. Organic fertilization consisted in applying 2.5 t ha^{-1} of cattle manure. Two irrigation assistance was provided after sowing (May 7 and June 7), two weeds were made (May 17 and June 8) and weed control was manual. The harvest was made after the genetic material reached physiological maturity.

Table 1. Identification code, place of collection, altitude and geographical coordinates where the collection sites of the 39 accessions are located.

Code	Collection place	Altitude (m)	Geographical coordinates
T1, T2, T3, T4, T5, T6, T8, T9	Acambay	2 440	19° 57’ 16’’ N 99° 50’ 39’’ W
T7	Jocotitlán	2 200-3 400	19° 42’ 26’’ N 99° 47’ 12’’ W
T10, T11, T12, T13, T14, T15, T16, T17, T18, T19, T34	Calimaya	2 690	19°10’ 25’’ N 99°37’ 02’’ W
T20	Mexicaltzingo	2 600	19° 13’ 15’’ N 99° 33’ 05’’ W
T23	Santa Cruz Atizapán	2 600	19° 09’ 27’’ N 99° 29’ 19’’ W
T21, T22, T24, T25, T37	Santiago Tianguistenco	2 622	19° 10’ 08’’ N 99° 28’ 01’’ W
T26, T33, T35	Toluca	2 680	19° 17’ 32’’ N 99° 39’ 14’’ W
T27	Zinacantepec	1 160	19°17’ 00’’ N 99° 44’ 00’’ W
T28	Almoloya del Rio	2 610	19°10’ 00’’ N 99° 29’ 00’’ W
T29, T30, T31, T32, T39	Metepec	2 635	19° 15’ 04’’ N 99° 36’ 17’’ W
T36	Lerma	2 570	19° 17’ 05’’ N 99° 30’ 43’’ W
T38	San Felipe del Progreso	2 570-2 650	19° 57’ 16’’ N 99° 50’ 39’’ W

Institute of Information and Geographic, Statistical and Cadastral Research of the State of Mexico (2011).

Registered variables

Ten plants were chosen as a sampling unit in each of the useful experimental units and 23 variables were recorded: 12 qualitative and 11 quantitative. The quantitative variables were number of stems (NT), number of knots (NN), number of leafs (NF0), percentage of flowering (PF), number of flowers per node (NFN), number of pods per plant (NVP), pod weight (PVP, g), number of seeds per pod (NSV), weight of 100 seeds (P100S, g). The seed weight was recorded by experimental plot (PSP) and with this the grain yield per hectare (RHA) was estimated. The qualitative variables registered with the technical guide for the varietal description of faba beans of the national service of inspection and certification of seeds (SNICS, 2000) were: habit of growth (HC), height of plant (AP), coloration of anthocyanins (CA), color of the foliage (CF) extension of the anthocyanin coloration in the flower (ECA), presence of the melanin spot in the wing (PMM), color of melanin spot in the wing (CMMA), melanin spot in the standard (MME), anthocyanin coloration on the standard (CAE), pot size (PV), degree of pod curvature (GCV), green pod coloring intensity (ICVV), seed shape (FS), color of the seed (CS) and presence of *hilium* (PH).

Statistical analysis

An analysis of variance was made, and its mean squares were used to calculate the components of variance and broad-spectrum heritability (H^2), the latter considered as an estimator of the genetic variability between accessions (Pérez *et al*., 2007). A comparison of means between cultivars was also performed with the Tukey test (α= 0.01). The arithmetic means of each cultivar for the 11 quantitative variables were used to obtain a data matrix: the cultivars were assigned to the rows and the values of each variable to the columns. With this matrix we obtained the analysis of the main components (ACP, Sánchez, 1995) and conglomerates (method of the unweighted arithmetic mean, UPGMA Method). Both analyzes were performed with the statistical analysis system Statistical Analysis System (SAS, 1988), but the biplot graph was made with Microsoft Excel 2010, using the scores of the first two main components (Pérez *et al*., 2009).

Results and discussion

Variance analysis

In the present study (Table 2) it was observed that the effects between cultivars were highly significant in number of knots (NN), percentage of flowering (DAF), number of flowers per plant (NF), pods per plant (NVP), weight of pod per plant (PVP), number of seeds per pod (NSV), weight of 100 seeds (P100S), weight of seed per plot (PSP) and yield per hectare (RHA). These results are similar to those reported by Yahia *et al*. (2012) and allow to deduce that for these variables the identification of outstanding genetic material is possible.

Table 2. Mean squares and statistical significance of the values of F for the quantitative variables.

FV	GL	NT	NN	NFo	PF	NFN
Repetitions	2	0.681 ns	1.44 ns	1.64 ns	1.44 ns	0.7 ns
Treatments	38	2.39*	8.16**	0.16 ns	192.59**	0.63**
Error	76	1.41	1.17	0.11	23.5	0.16
Total	116					
CV (%)		18.59	10.5	6.89	26.73	9.06
X		6.39	10.3	4.85	18.13	4.51

**= significant at 0.01; *= significant at 0.05; ns= not significant; FV= source of variation; CV= coefficient of variation; GL= degrees of freedom; NT= number of stems; NM= number of knots; NFo= number of leafs; PF= percentage of flowering; NFN= number of flowers per knots.

Table 2. Mean squares and statistical significance of the values of F for the quantitative variables (continuation).

FV	GL	NVP	PVP	NSV	P100S	PSP	RHA
Repetitions	2	2.03 ns	72.23 ns	0.071 ns	121.53 ns	16.38 ns	0.097 ns
Treatments	38	347.3**	5326.08**	0.21**	4857.08**	4274.45**	3.878**
Error	76	0.99	16.21	0.027	327.84	7.9	0.102
Total	116						
CV (%)		5.65	4.99	9.46	9.55	4.3	15.57
X		17.65	80.63	1.74	189.59	65.36	2.06

**= significant at 0.01; *= significant at 0.05; ns= not significant; FV= source of variation; CV= coefficient of variation; GL= degrees of freedom; NVP= number of pods per plant; PVP= pod weight per plant; NSV= number of seeds per pod; P100S= weight of 100 seeds; PSP= weight of seeds per plot; RHA= yield per hectare (RHA).

Components of variance and heritability

The components of variance (CV) are evaluated in terms of response to the selection and the use of the moment method, calculated with its linear functions, allows estimating the genetic variability (H^2) that exists between cultivars when using the mean squares of the analysis of variance (Shimelis and Shringani, 2010). In the present study it was observed that in the majority of quantitative traits the H^2 varied from 30.7 to 99.8% (Table 3). In quantitative traits, such as seed yield, it is desirable that H^2 values are greater than 50% (Filippeti and Ricciardi, 1988; Khare and Singh, 1991; Bakheit, 1992) to contribute to a greater response to selection or to optimize the genotype x environment association. Alan and Geren (2007) reported heritabilities less than 50% in plant height (29%), number of stems (17.6%), pods per plant (3%), seeds per pod (47%) and weight of 100 seeds (30%).

Table 3. Components of variance and heritability in a broad sense (H^2) in 11 quantitative variables evaluated in 39 faba bean cultivars.

Variable	$\sigma_G{}^2$	$\sigma_f{}^2$	H^2
NT	0.32	0.79	40.5
NN	2.33	2.72	85.6
NFo	0.016	0.052	30.7
PF	53.36	61.19	87.2
NFN	0.15	0.2	75
NVP	115.4	115.73	99.7
PVP	1769.9	1775.3	99.6
NSV	0.061	0.07	87.1
P100S	1509.7	1618.9	93.2
PSP	1422.18	1424.81	99.8
RHA	125	128	97.6

Number of stems (NT); number of knots (NN); number of leafs (NFo); flowering percentage (FP); number of flowers (NF); number of pods per plant (NVP); pod weight per plant (PVP); number of seeds per pod (NSV); weight of 100 seeds (P100S); seed weight per plot (PSP) and yield per hectare (RHA).

Principal component analysis

In the biplot that was constructed with the cultivars and the variables, it was observed that the main components 1 (41.6%) and 2 (23.6%) explained 65.2% of the original total variation (Figure 1). Sánchez (1995); Pérez *et al*. (2009) mentioned that this percentage is desirable to interpret reliably the approximate correlations that exist between both. The dispersal of the 39 cultivars in the four quadrants of the biplot suggests that there is genetic variability that is available to initiate a new breeding program. Phenotypic variability was detected in 39 collections faba bean was higher in NN, PF, NF, NVP, PVP, P100S, PSP and RHA. Collecting 8 (T8) from Tixmadejo, Municipality of Acambay, he showed a yield of 4.16 t ha^{-1}, more than the national average value is 0.99 t ha^{-1}. T8 also showed superiority in number of knots (11.76), flowering percentage (90%) and pod weight per plant (152.83 g), followed by P5 (Pueblo Nuevo, Acambay) and P27 (Santa Cruz Cuauhtenco, Zinacantepec) (Table 4).

These results are similar to those observed by Neal and Mcvetty (1983) who concluded that 68.5 to 76.4% of the variability in seed yield is due to the number of pods produced per plant (Singh *et al*., 1987; De Costa *et al*., 1997; Chaieb *et al*., 2011), to seeds per pod (Alan and Geren, 2007), to the weight of 100 seeds (Baginsky *et al*., 2013) and to the size of the seed (Al-Refaee *et al*., 2004; Mohammed *et al*., 2013). Although the number of pods per plant has been considered by many authors as the main source of variation in the yield of the faba bean crop (under very favorable conditions there is an excess of pods and also of abortions), the number of seeds per square meter (depending on the number of pods) is the factor that most affects performance.

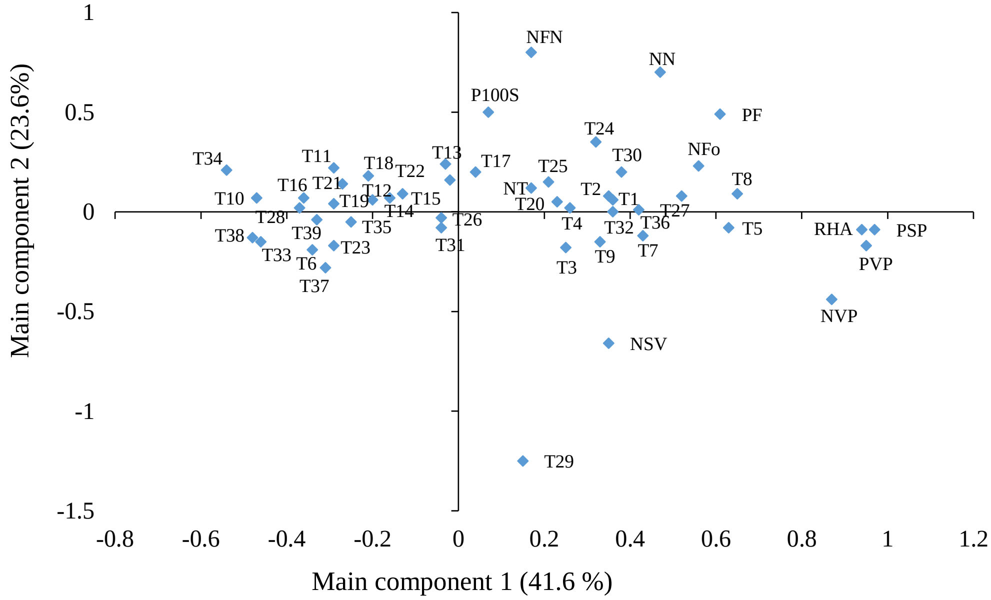

Figure 1. Interrelations between 39 faba bean cultivars (in number) and 11 agronomic variables (in letter).

Table 4. Comparison of means of 11 agronomic variables.

Code	NT	NN	NFo	PF	NFN	NVP
T1	7.7 a	11.73 ab	4.93 a	87.53 ab	4.43 a	26.93 e-g
T2	7.56 a	10.56 a-d	4.76 a	79.44 ab	4.73 a	23.33 g-h
T3	7.56 a	10.96 a-c	4.93 a	86.84 ab	4.43 a	25.03f-h
T4	4.43 a	11.3 a-c	5.03 a	75.59 a-c	4.5 a	22.33 h-i
T5	7.66 a	11.36 a-c	5.2 a	79.44 ab	4.56 a	37.5 b
T6	5.83 a	8.63 a-f	4.46 a	64.41 a-d	3.9 ab	14.03 kl
T7	6.1 a	11.36 a-c	4.8 a	77.06 ab	4.26 a	33.7 c-d
T8	6.7 a	11.76 ab	5.1 a	90.9 a	4.86 a	35.5 b-c
T9	6.1 a	10.43 a-d	4.86 a	57.28 a-f	4.6 a	29.03 e
T10	5.93 a	10 a-e	4.53 a	64.51 a-e	4.5 a	3.73 o-p
T11	7.73 a	9.96 a-e	4.46 a	63.41 a-e	4.76 a	7.5 n
T12	5.7 a	10.96 a-c	4.73 a	59.14 a-g	4.46 a	12.06 lm
T13	7.2 a	11.3 a-c	5.06 a	62.2 a-e	4.46 a	12.66 lm
T14	5.1 a	10.63 a-d	4.8 a	53.79 a-g	4.63 a	13.36 kl
T15	5.56 a	10.86 a-c	4.86 a	45.78 a-g	4.53 a	12.36 lm
T16	5.9 a	11.2 a-c	4.6 a	51.17 a-g	4.26 a	7.7 n
T17	6.33 a	11 a-c	4.96 a	72.39 a-c	5 a	16.53 j-k
T18	6.63 a	10.56 a-d	5 a	63.89 a-e	4.56 a	8.1 n
T19	5.4 a	10.93 a-c	5.03 a	63.79 a-e	4.4 a	7.16 no
T20	6.66 a	11.43 a-c	5.1 a	69.13 a-c	4.53 a	23.43 g-h
T21	6.56 a	9.96 a-e	4.7 a	69.13 a-c	4.93 a	9.03 m-n

Code	NT	NN	NFo	PF	NFN	NVP
T22	7.03 a	10.76 a-d	4.76 a	72.03 a-c	4.76 a	13.93 kl
T23	5.73 a	10.36 a-d	4.5 a	57.44 a-g	4.23 a	12.66 lm
T24	6.26 a	11.96 a	4.83 a	75 ab	4.6 a	16.93 j-k
T25	7.26 a	11.66 ab	5.1 a	80.64 ab	4.93 a	21.76 h-i
T26	5.2 a	11.03 a-c	4.8 a	56.1 a-g	4 a	16.76 j-k
T27	7.56 a	11.8 ab	4.93 a	79.11 ab	4.9 a	27.6 e-f
T28	6.1 a	10.3 a-e	4.36 a	63.79 a-e	4.4 a	3.43 p
T29	5.73 a	4.7 f	4.56 a	0 g	2.43 b	48.23 a
T30	6.5 a	10.93 a-c	5.26 a	60.36 a-g	5.36 a	23.03 h
T31	5.83 a	9.73 a-e	4.86 a	46.66 a-g	4.06 a	18.9 i-j
T32	5.83 a	11.36 a-c	4.96 a	71.89 a-c	4.9 a	29.36 e
T33	6.96 a	06.3 e-f	4.86 a	2.024 f-g	4.8 a	5.56 n-p
T34	6.43 a	10.96 a-c	4.66 a	38.7 b-g	4.53 a	2.9 p
T35	7.93 a	6.83 d-f	5.36 a	2.024 f-g	4.83 a	12.16 lm
T36	6.13 a	11.73 ab	5.13 a	75.75 ab	4.83 a	30.03 de
T37	7.03 a	7.8 b-f	4.76 a	9.58 e-g	4 a	7.8 n
T38	7.96 a	7.46 c-f	4.66 a	11.22 d-g	4.7 a	7.4 no
T39	4.56 a	8.96 a-e	4.8 a	25.42 c-g	4.3 a	9.1 m-n

NT= number of stems; NN= number of knots; NFo= number of leaflets; PF= percentage of flowering; NFN= number of flowers; NVP= number of pods per plant. Mean values with the same letter within each column are statistically equal (Tukey, $p = 0.01$).

Table 4. Comparison of means of 11 agronomic variables (continuation).

Code	PVP	NSV	P100S	PSP	RHA
T1	112.23 ef	1.73 c-e	186.8 b-k	100.66 fg	3.1 a-f
T2	133.43 c	1.8 cd	236.13 b-d	107.63 d-f	3.33 a-e
T3	91.66 gh	2.5 a	142.63 h-l	71.23 ij	2.16 e-l
T4	109.36 f	1.83 b-d	209.07 b-h	97.46 fg	2.96 b-g
T5	139.40 a-c	2.03 a-d	170 d-l	127.3 ab	3.9 ab
T6	64.56 k-n	1.56 de	141.33 i-l	26.56 s-v	0.82 m-p
T7	151.23 ab	1.63 de	139.73 j-l	115.13 cd	3.56 a-c
T8	152.83 a	1.73 c-e	190.6 b-k	135.2 a	4.16 a
T9	130.73 cd	2.03 a-d	181.6 c-k	105.23 d-g	3.23 a-e
T10	16.9 tu	1.63 de	167.73 e-l	12.2 wx	0.37 p
T11	48.7 o-r	1.5 de	241.33 bc	36.03 p-s	1.1 k-p
T12	52.56 n-q	1.63 de	187.87 b-k	44.36 n-p	1.33 j-p
T13	69.86 j-m	1.46 de	237.6 bc	58.06 k-m	1.76 h-m
T14	60.86 l-o	1.6 de	184 c-k	48.53 m-o	1.46 i-p
T15	64.9 k-n	1.63 de	213.33 b-g	52.56 l-n	1.6 i-o
T16	39.53 q-s	1.53 de	191.8 b-k	27.8 s-v	0.86 m-p
T17	77 h-k	1.63 de	197.87 b-k	65.9 jk	2 f-m
T18	44.7 p-r	1.6 de	202.93 b-j	32.7 q-t	0.99 l-p

Code	PVP	NSV	P100S	PSP	RHA
T19	29.3 st	1.8 cd	148 g-l	21 u-w	0.65 op
T20	103.06 fg	1.73 c-e	177.33 c-l	82.76 h	2.53 c-i
T21	39.3 q-s	1.63 de	165.73 f-l	29.63 r-u	0.92 m-p
T22	73.06 i-l	1.7 c-e	215.47 b-f	59.6 kl	1.8 g-n
T23	46.56 o-r	1.93 a-d	133.87 kl	33.8 q-s	1 l-p
T24	127.56 cd	1.43 de	334.93 a	114.4 c-e	3.53 a-d
T25	87.26 hi	1.8 cd	167.2 e-l	76.7 hi	2.36 d-j
T26	87.5 hi	1.56 de	195.33 b-k	65.43 jk	2 f-m
T27	136.33 bc	2.03 a-d	222.93 b-f	123.06 bc	3.8 ab
T28	16.73 tu	1.63 de	163.83 f-l	12.33 wx	2.6 c-i
T29	137.86 bc	2.43 ab	111.2 l	107.7 d-f	3.3 a-e
T30	125.86 c-e	1.63 de	209.6 b-h	112.23 de	3.43 a-d
T31	82.5 h-j	1.53 de	194.67 b-k	72.43 h-j	2.2 e-k
T32	117.23 d-f	1.9 a-d	177.47c-l	104.63 e-g	3.23 a-e
T33	36 rs	1.93 a-d	207.87 b-i	23.26 t-v	0.72 n-p
T34	11.1 u	1.16 e	159.87 f-l	9.1 x	0.28 p
T35	55.3 m-p	1.53 de	166.53 f-l	40.7 o-q	1.23 j-p
T36	134.76 c	1.93 a-d	158.4 f-l	95.06 g	2.93 b-h
T37	52.8 n-q	2.26 a-c	252 b	39.43 o-r	1.2 j-p
T38	29.26 st	1.83 b-d	175.33 c-l	18.23 v-x	0.56 op
T39	54.7 n-p	1.56 de	234.27 b-e	43.03 n-q	1.3 j-p

PVP= pod weight per plant; NSV= number of seeds per pod; P100S= weight of 100 seeds; PSP= weight of seed per plot; RHA= yield per hectare. Mean values with the same letter within each column are statistically equal (Tukey, *p*= 0.01).

Conglomerate analysis

In the dendrogram of Figure 2, when cutting at an average distance between conglomerates of 0.8 units, four groups were identified. In group IV only cultivar 24 was observed, from Santiago Tianguistenco, with significant values in NN, NFo, NFP and P100S, it was the highest with respect to all populations and had 3.53 t ha^{-1}. These results are similar to those found by Alan and Geren (2007) and Baginsky *et al*. (2013), who commented that these characters have an important influence on performance.

In group II, cultivars identified as T7 and T29, from Los Reyes, Jocotitlan and San Isidro de Metepec variety, respectively, showed desirable characteristics in NT, NFo, PVP and produced more than 3 t ha^{-1}, group I was made up of T1, T32, T9, T36, T5, T8, T2, T27, T4, T30, T3, T26, T31, T17, T20 and T25, the first 13 belong to the northern and central part of the Valley Toluca-Atlacomulco, the last three to the south-east zone, in terms of the agronomic traits evaluated is the most important group because it agglomerates the best populations. In contrast, in group III the rest of the cultivars were classified with the lowest average values. Such results coincide with Duc *et al*. (2010), who commented that the response of genotypes is differential, since the adaptation to the environment and its interaction with it is determinant in a desirable phenotypic expression.

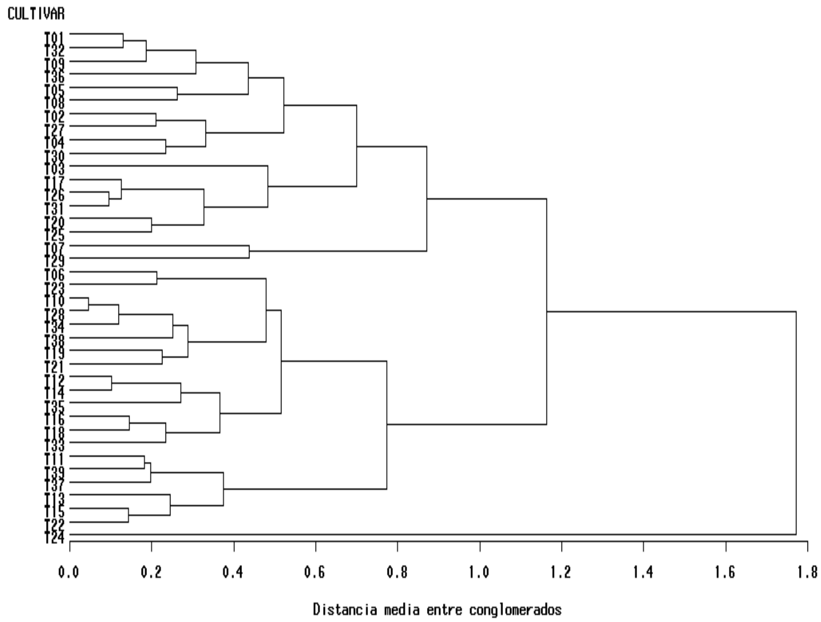

Figure 2. Grouping of 39 faba bean cultivars based on 11 agronomic variables. Method of grouping unweighted pairs with arithmetic means (UPGMA method).

Qualitative characteristics

The identification of genetic variability between and within cultivars allows selecting varieties with desirable agronomic characteristics and contributes to the partial increase of the production and quality of the faba bean seed. The varietal description allows an easy and rapid discrimination between phenotypes (Franco and Hidalgo, 2003), they are generally considered highly heritable characteristics, easily detected with the naked eye and with little or no variation through the environments (Pérez *et al*., 2007). In this investigation, phenotypic differences were observed in the 39 populations in determinate (D) growth habit (HC) and gray-green color, except for T29 (San Isidro) that was green and T35 that was bluish green, 12 cultivars showed anthocyanin coloration in foliage, the extent of anthocyanin coloration was large only in T8, in 23 populations was medium and in 15 small, the presence of melanin spot was recorded by all populations, the color of the spot was brown, there was presence of melanin spot but with absence of coloration (Tables 5 and 6).

The pod size was semi-erect in 26 populations, erect in eight and horizontal in five, this is important for producers since an recto angle of the pod favors physiological maturity, mechanized harvest and resistance and tolerance to drought (Gresta *et al*., 2009), there was no degree of curvature in 24 populations, two were of medium curvature and 13 weak, the green intensity of the pod was medium in 20 populations, weak in 13 and strong in six. The shape of the seed was ovate in 21 populations, oblong in 15, elliptical in two and only in T29 was rectangular, the color of the seed was light brown in all the populations except in T30 that was marbled, all the materials presented *hilium* (Table 7). The morphological characters of qualitative type, such as habit of growth of the leaves and flowers, among others, are those that allow the visual identification of the genotypes in the field, but a greater or lesser uniformity and adaptation of the genotypes will influence their use final by the producers (Madriz and Luciani, 2002).

Table 5. Plant and foliage characteristics of 39 faba bean populations collected in the Valley Toluca-Atlacomulco, Mexico.

Code	Plant		Foliage	
	HC	A	CA	C
T1	D	M	P	VG
T2	D	M	P	VG
T3	D	M	P	VG
T4	D	M	P	VG
T5	D	A	P	VG
T6	D	A	A	VG
T7	D	A	P	VG
T8	D	A	P	VG
T9	D	M	P	VG
T10	D	A	A	VG
T11	D	A	A	VG
T12	D	A	A	VG
T13	D	M	A	VG
T14	D	M	A	VG
T15	D	M	A	VG
T16	D	M	A	VG
T17	D	A	A	VG
T18	D	M	A	VG
T19	D	M	P	VG
T20	D	A	P	VG
T21	D	M	A	VG
T22	D	M	A	VG
T23	D	M	A	VG
T24	D	A	A	VG
T25	D	M	A	VG
T26	D	M	A	VG
T27	D	A	A	VG
T28	D	M	A	VG
T29	D	B	A	V
T30	D	M	P	VG
T31	D	A	A	VG
T32	D	A	A	VG
T33	D	M	A	VG
T34	D	M	A	VG
T35	D	M	A	VA
T36	D	M	P	VG
T37	D	M	A	VG
T38	D	M	A	VG
T39	D	M	A	VG

Habit of growth; D= determined; I= indeterminate; A= height; B= low; M= medium; A= high; CA= anthocyanin coloration; P= present; A= absent; C= color; V= green; VA= bluish green; VG= grayish green.

Table 6. Flower characteristics of 39 faba bean populations collected in the Valley Toluca-Atlacomulco, Mexico.

Code	Flower					
	LF	ECA	PMM	CM	MM	CA
T1	G	M	P	C	P	A
T2	G	M	P	C	P	A
T3	G	P	P	C	P	A
T4	G	M	P	C	P	A
T5	G	M	P	C	P	A
T6	G	M	P	C	P	A
T7	G	M	P	C	P	A
T8	G	G	P	C	P	A
T9	G	M	P	C	P	A
T10	G	P	P	C	P	A
T11	G	M	P	C	P	A
T12	G	M	P	C	P	A
T13	G	P	P	C	P	A
T14	G	M	P	C	P	A
T15	G	P	P	C	P	A
T16	G	P	P	C	P	A
T17	G	M	P	C	P	A
T18	G	P	P	C	P	A
T19	G	P	P	C	P	A
T20	G	P	P	C	P	A
T21	G	M	P	C	P	A
T22	G	M	P	C	P	A
T23	G	P	P	C	P	A
T24	G	P	P	C	P	A
T25	G	M	P	C	P	A
T26	G	M	P	C	P	A
T27	G	P	P	C	P	A
T28	G	M	P	C	P	A
T29	M	P	P	C	P	A
T30	G	M	P	C	P	A
T31	G	P	P	C	P	A
T32	G	P	P	C	P	A
T33	G	M	P	C	P	A
T34	G	M	P	C	P	A
T35	G	M	P	C	P	A
T36	G	M	P	C	P	A
T37	M	M	P	C	P	A
T38	G	M	P	C	P	A
T39	M	P	P	C	P	A

LF= flower length; M= median; G= large; ECA= extension of anthocyanin coloration; P= small; M= median; G= large; PMM= presence of melanin spot P= present; A= absent; CM= color of the stain; C= brown; MM= melanin stain; P= present; A= absent; CA= coloration of anthocyanins; P= present; A= absent).

Table 7. Pod and seed characteristics of 39 faba bean populations collected in the Toluca Valley.

Code	Pod			Seed dry		
	PV	GCV	ICVV	FS	CS	PH
T1	SE	A	M	O	CC	P
T2	E	A	M	O	CC	P
T3	E	A	M	O	CC	P
T4	H	M	D	E	CC	P
T5	E	A	D	O	CC	P
T6	SE	D	D	E	CC	P
T7	SE	D	M	O	CC	P
T8	E	A	M	O	CC	P
T9	SE	A	M	Ov	CC	P
T10	E	D	M	Ov	CC	P
T11	SE	A	M	Ov	CC	P
T12	SE	A	M	Ov	CC	P
T13	SE	A	F	Ov	CC	P
T14	H	D	F	Ov	CC	P
T15	H	D	F	Ov	CC	P
T16	SE	A	D	Ov	CC	P
T17	SE	A	M	Ov	CC	P
T18	SE	D	D	Ov	CC	P
T19	SE	D	D	Ov	CC	P
T20	SE	A	M	Ov	CC	P
T21	H	D	F	Ov	CC	P
T22	E	A	D	Ov	CC	P
T23	SE	D	F	O	CC	P
T24	SE	A	M	Ov	CC	P
T25	SE	A	M	Ov	CC	P
T26	SE	D	M	O	CC	P
T27	SE	A	D	O	CC	P
T28	SE	D	D	Ov	CC	P
T29	E	A	M	R	CC	P
T30	SE	A	D	O	J	P
T31	SE	D	D	O	CC	P
T32	SE	A	D	O	CC	P
T33	SE	D	F	O	CC	P
T34	H	M	D	O	CC	P
T35	E	A	M	O	CC	P
T36	SE	A	M	Ov	CC	P
T37	SE	A	M	Ov	CC	P
T38	SE	A	M	Ov	CC	P
T39	SE	A	M	Ov	CC	P

PV= pod size; SE= semierect; E= erect; H= horizontal; GCV= degree of curvature of the pod. A= absent, D= weak; M= median; ICVV= intensity of green color of the pod. D= weak; M= median; F= strong; FS= shape of the seed; O= oblong; E= elliptical; O = ovate; R= rectangular; CS= color of the seed; CC= light brown, J: marbled; PH= presence of *hillium*; P= present.

Conclusions

The principal component and conglomerate analyze allowed to identify cultivars 8, 5 and 27 as superior in seed yield. Wide phenotypic variability was also observed in NN, PF, NF, NVP, PVP, P100S, PSP (H2 values of 75 to 99.8%). In relation to the qualitative characteristics, little phenotypic variability was detected in the evaluated characters.

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