Performance of common bean landraces from Spain in the Atlantic and Mediterranean environments

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Abstract

Ninety-five common bean (*Phaseolus vulgaris* L.) landraces from Spain were evaluated in three different environments in northern Spain for their agronomic performance and seed quality. Significant differences among landraces were found for 14 quantitative traits related to phenology, yield and its components, and seed quality traits. Environmental effects were significant for all traits evaluated except for seeds pod^{-1}, seed width/thickness, seed weight, and seed water absorption. Landrace by environment interactions were significant for all traits except for seeds pod^{-1} and seed water absorption. Selection of new breeding lines for agronomic performance and seed quality within landraces should be reliable because many of them are mixture of lines. Some heirloom varieties belonging to the types "faba", "caparrón", "riñón", "ganxet" and "tolosana" had the best performances regarding to seed quality and yield. Principal component analysis revealed differences among environments affecting the performance of the bean landraces. Variation in the landraces seems to be organized in a different way in each one of the test environments, therefore, low plasticity and specific adaptation of Spanish bean landraces to different environments is derived from this study. Some landraces, especially those large and white seeded should be an useful resource for sustainable farming systems in different biogeographical areas and a worthy germplasm for the genetic improvement of agronomic value and seed quality.

Key words: environment interaction, germplasm, *Phaseolus vulgaris*, plant breeding, principal component analysis.

Introduction

Traditional landraces of crops are present nowadays in agricultural systems in many countries all around the world. Agriculture, characterized by the use of landraces of crops, is often a source of genetic diversity for plant breeding. Major advantages of landraces are adaptation to their specific agrosystems and low input requirements but ethnic reasons are also present in traditional agriculture practices.

Introduction of common bean into Europe could have implied a bottleneck because probably few types of seeds came from the Americas by means of sailors and traders. Later on the species experienced a secondary diversification in Southern Europe (Santalla et al. 2002) that resulted in new variation that enlarged the genetic diversity of the European bean germplasm. The landraces evolved from ancient types by conscious or unconscious phenotypic selection by farmers. Therefore, they are currently well adapted to the agroecological conditions under which they have been grown for centuries. During their evolution in Europe bean landraces were selected by growers according to their customs and the specific requirements of each area of cultivation, resulting in different heirloom varieties.

Bean germplasm related to ethnic customs are suitable to small-scale production for niche markets that means an opportunity for direct market farmers (Miles 2002). Interest of growing traditional bean landraces is based upon their adaptation to specific agrosystems, their quality that satisfies the requirements of farmers, traders and consumers, and their low input needs, specially when intercropped with maize (Santalla et al. 1994), in a sustainable farming system.

Bean growers have the chance for direct use of valuable landraces for local or niche markets but sometimes environmental conditions could be major constrains. Environmental effects and genotype by environment interactions could affect the stability of quantitative traits that are important for genetic improvement (Lin et al. 1986, Mekbib 2003). The comparison of different varieties over a series of environments results in a range of different scores which causes difficulty in displaying the superiority of any variety. Therefore, the performance of such landraces must be verified under different conditions in representative growing environments. In some areas where bean is a traditional crop there are distinct biogeographic dominions. In the Iberian Peninsula, bean is often cultivated in the Atlantic and Mediterranean dominions which differ clearly in their environmental conditions (Font 2000).

The objectives of this research were: i) to evaluate the variation in traits affecting agronomic value and seed quality in traditional dry bean landraces from Spain, ii) to estimate the performance of these landraces under different agro-ecological environments, and iii) to define the role of the available bean landraces variation in sustainable farming systems and their use in breeding for new cultivars.

Material and methods

Plant material. Ninety-five Spanish common bean accessions from the germplasm collection at the Misión Biológica de Galicia (MBG-CSIC, Pontevedra, Spain) (De Ron et al. 1997) were evaluated in this study. They are popular traditional dry bean varieties or heirloom cultivars together with some varieties from local traders grown in Spain (Table 1) under different agro-ecological conditions through the Atlantic and Mediterranean biogeographic dominions (Figure 1).

Experimental design. Landraces were evaluated in 1994 in three locations in Spain: Lalín (42º 36' N, 8º 8' W, 500 masl, average temperature 11.7 ºC, average annual rainfall 1200 mm), environment showing intermediate conditions among the Atlantic and the Mediterranean biogeographic dominions; Pontevedra (42º 26' N, 8º 38' W, 40 masl, average temperature 14.6º C, average annual rainfall 1600 mm) in the Atlantic biogeographic dominion; and Vitoria (42º 51' N, 2º 40' W, 530 masl, average temperature 11.7 ºC, average annual rainfall 840 mm) in the Mediterranean biogeographic dominion. The field trials were arranged as randomized complete blocks with two replications. Each landrace was sown in a 15 plant-row with row to row distance of 0.80 m and plant to plant distance of 0.25 m, equivalent to a crop density of 50,000 plants ha^{-1}.

Evaluation data. During the growing period, data related to phenology, yield and yield components and seed characteristics were recorded (Puerta-Romero 1961, CIAT 1983, De la Cuadra et al. 2001). Phenology (on a plot average basis): beginning of flowering (days from sowing until 50% of plants in each plot had at least one open flower), end of flowering (days from beginning of flowering until 50 % of plants had no open flowers), physiological maturity (days from sowing until 90 % of plants had dry pods ready for seed harvest). Yield and yield components: seeds pod^{-1} (determined on five pods per plot), pods $plant^{-1}$ and yield (g $plant^{-1}$) (on a plot basis). Seed characteristics (after storage at 4 ºC and 45 % of air humidity during two months): length, width and thickness (determined on 10 seeds per plot, in millimetres), length/width and width/thickness indexes, seed weight (g 100 seeds^{-1}), water absorption (the amount of water dried seeds absorb during soaking determined by soaking 100 dry seeds for 18 hours in distilled water at 15 ºC and dividing the difference in weight before and after soaking by the dry weight of the 100-seed sample), and seed coat proportion (determined on 10 seeds per plot, it was the relation in weight between coat and cotyledon plus seed coat expressed in percentage, after removing the seed coat from the cotyledon, both after soaking and keeping them for 24 h at 105 ºC). Growth habit, and seed colour and shape were also recorded.

Data analysis. Analyses of variance were performed by the GLM procedure (SAS Institute 2000) for all the quantitative traits studied considering landraces and environments as random effects. Principal component analysis (PCA) was made by the NTSYS-pc package (Rohlf 2000) using 10 quantitative variables related to: phenology (beginning of flowering, end of flowering and physiological maturity), seed size (length, width, thickness, and weight), yield and yield components (seeds pod^{-1} and pods plant^{-1}).

Results

Landrace characteristics are shown in Table 2. Fifty-two bean landraces were white seeded and six were bi-coloured (white and purple). Fifty landraces had extra-large seeds (≥60 g 100 seeds^{-1}) and 36 had large seeds (40-59 g 100 seeds^{-1}). Regarding to the growth habit, 32 landraces from the Atlantic biogeographic dominion showed indeterminate climbing type IV and 15 determinate type I whereas 16 landraces from the Mediterranean dominion had indeterminate type IV and 15 determinate dwarf type I.

The Table 3 displays the analysis of variance, range of variation, mean and coefficient of variation for the quantitative traits evaluated. Significant differences among landraces were found for all the quantitative traits. No significant environmental effect was detected for seeds pod^{-1}, seed width/thickness, seed weight and seed water absorption while all traits except seeds pod^{-1} and seed water absorption showed a significant landrace x environment interaction.

Figures 2a, 2b and 2c show the distribution of the studied bean landraces along the first (PC 1) and second (PC 2) principal components in three environments. As a reference the overall averages of landraces in each environment (Lalín, Pontevedra and Vitoria) were also included in the analysis.

Figure 2a display the distribution of landraces in Lalín according to the PCA analysis. PC 1 accounted for the 35.0 % of the variation and it represents the seed size and PC 2, that represented the yield and phenological traits, accounted for the 24.9 % of the variation. Figure 2b shows the plotting of the bean landraces in Pontevedra in the PCA analysis. PC 1 represents yield, seed size, and phenological traits accounting for the 38.8 % of the variation and PC 2, that scored the 25.4 %, represented variation for yield components. The distribution of the landraces in Vitoria according the PCA analysis is shown in figure 2c. Variation for seed size and phenological traits is indicated by PC 1, accounting for the 38.4 % of variation while PC 2, with 24.7 % of the variation, represented the yield and yield components.

Discussion

Two peculiar characteristics of the bean germplasm studied are seed colour and size. White seeded beans are preferred by Spanish consumers which is reflected in most of the landraces cultivated by farmers and marketed by local dealers and traders as reflected in the results of this work. Breeding for large-seeded beans is discussed by Beaver (1999), considering as large those ones with 30-40 g 100 seeds^{-1} in warm areas and 50-60 g 100 seeds^{-1} in temperate and cool areas. In this study, the 100-seed weight between 40 and 59 g was considered as large and over 60 g was considered as extra-large. Previous studies of Spanish and Portuguese germplasm confirmed the preferred dry bean seed type in these areas. Rodiño et al. (2001) reported 28.4 % of white seeds and 46.6 % of large seeds in Portuguese bean germplasm and Escribano et al. (1997) found 45.8 % of white seeds and 83.1 % of large and extra-large seeds in bean landraces from northwestern Spain.

The ancient custom of intercropping maize and bean in the north and northwest of the Iberian Peninsula affects the favourite growth habit of beans giving to the farmers the choice to use the maize stalk as an inexpensive support for climbing beans. It is reflected in the high proportion of the indeterminate climbing type IV landraces and the low proportion of determinate dwarf type I landraces in the Atlantic biogeographic dominion. On the other hand, in the Mediterranean dominion where monoculture is the common practice, proportion of types I and IV were similar.

Significant differences among landraces for the quantitative traits evaluated agreed with previous studies by Natarajan and Arumugan (1979), Joshi and Mehra (1984), Gil and De Ron (1992) and Escribano et al. (1994). The presence of landrace x environment interactions is in agreement with the results reported by Vaid et al. (1985) and Escribano et al. (1994). Saidon and Schaalje (1993) evaluated genotype x environment (GE) effects in regional registration trials for dry beans (*Phaseolus vulgaris*) in western Canada to determine whether geographic distribution of sites could be rationalized. Nienhuis and Singh (1986) and Sills and Nienhuis (1993) have reported environmental effects in the expression of quantitative traits in dry and snap beans. These environmental effects and the interactions between genotype and environment highlight the different response of the bean landraces to the environmental conditions. This means that the best genotype for one environment is not the best for another (Falconer and Mc Kay, 1996). Therefore, the development of specific types has been proposed by Hosfield et al. (1984) in dry bean to overcome the interaction genotype by environment.

Natural selection takes place while advancing generations of populations of self pollinating species. Pirola et al. (2002) observed that while advancing segregant populations by the population (bulk) method, natural selection acted to preserve the individuals which are more adapted to the environment in which they were advanced. Mekbib (2003) evaluated bean genotypes under different representative growing environments in Ethiopia in traits with fair stability and pointed out the need for evaluation under variable environments and simultaneous selection for yield and stability. In the present work, some relevant traits for breeding such as seeds pod^{-1}, water absorption and seed weight showed stability across the environments studied that means an opportunity for breeding for yield and quality components in either the Atlantic or the Mediterranean biogeographic dominion.

The wide ranges of variation displayed by all the traits emphasize strongly the possibilities for selection within the landraces because many of them are actually mixture of lines. Bean mixtures of different types according to some characteristics such as seed colour and pattern are often seen in farmer fields and markets in many countries (Kaplan 1981, Traka-Mavrona et al. 2000, Rodiño 2001, De Ron et al. (in press), Piergiovanni et al. (in press)). In the present research each landrace was evaluated according to its average value for each quantitative trait and the seed was described according to the most representative type in the mixtures. Nevertheless, some variation could exist that was not reflected in the phenotypic variation here reported. Thus, to split the mixed landraces in different lines is a need for further selection tasks. Specific traits that could give added value to these lines merit further research since they could be introgressed to other dry bean cultivars by hybridization and backcross.

Sensorial attributes of the seed as low coat proportion and high water absorption are indicators of cooking quality. The “faba” landraces had the best scores for water absorption together with other white types as “caparrón”, “ganxet”, and “alubia”. Regarding to seed coat proportion, the best were the heirloom bi-coloured varieties “caparrón” and some white types such as “faba”, “riñón”, and “redonda”. Taken into account the two sensorial traits evaluated, “faba” landraces PHA-0123 and PHA-0222, “riñón” landrace PHA-0267, “caparrón” landrace PHA-0404, and “alubia” landrace PHA-0536 had the best performance, therefore they are suitable for production for niche markets in Spain. Regarding to seed yield, “faba” landraces (PHA-0222, PHA-0330, PHA-0600 and PHA-0616), “caparrón” landraces (PHA-0331, PHA-0569 and PHA-0608), “planchada” landraces (PHA-0419 and PHA-0609) and “tolosana” landraces (PHA-0425 and PHA-0630) had the best performances. PHA-0123, PHA-0222, PHA-0331 and PHA-0419, with indeterminate climbing growth habit could be adequate for intercropping in the Atlantic dominion. Other landraces such as PHA-0600, with growth habit type II, PHA-0267, PHA-0404, and PHA-0536, with dwarf habit should be suitable for monoculture.

A global approach to the PCA indicates that the variation in the studied landraces appears to be organized in a different way in each one of the environments where they were tested.

Lalín (Figure 2a) is an intermediate location between the Atlantic and Mediterranean biogeographic dominions and it seems to be a suitable agrosystem for growing the extra-large seeded “faba” landraces that displayed very good seed size and adequate agronomic performance. Beans belonging to the "faba" type are often cultivated in Galicia and Asturias (northwestern Spain). In Asturias the traditional variety “faba” is protected by a legal regulation based upon its peculiar characteristics while in Galicia this regulation will be adopted in a future for similar dry bean types. Under the environmental conditions of Lalín, some Mediterranean landraces such as “faba” (PHA-0600 and PHA-0616) and “ganxet” (PHA-0623) had an adequate performance. Landraces PHA-0271, PHA-0376 and PHA-0381 had high productivity.

“Faba” and “planchada” heirloom varieties from the Atlantic dominion are the best performers in the typical Atlantic conditions at Pontevedra (Figure 2b), ranging from small to extra-large seeded types and being mostly white or black seeded varieties. Nevertheless, two Mediterranean landraces, namely PHA-0630 (“tolosana”) and PHA-0623 (“ganxet”) showed good values too. Landrace PHA-0271 had high yield. Performance of traditional bean landraces under this environment seems to be independent of their commercial type and geographic origin. Northwestern Spain displays high diversity of common bean types (Gil and De Ron 1992) and this region was documented as a centre for secondary diversification of bean in Europe (Santalla et al. 2002). The socioeconomic conditions of Galicia (the love to the land does that the Galicians preserve the property of the smallholdings of their forbears) and the travelling tradition of Galicians (sailors and emigrants) have contributed to diversification by exchange of seeds of bean and other crops in Galicia. Hence, many landraces from different origins in Spain should trace back their origin to this Atlantic area which should explain their good behaviour in this environment.

Vitoria (Figure 2c) is a representative environment within the Mediterranean biogeographic dominion. Some landraces from Mediterranean origin are good performers in this environment: PHA-0569 (“caparrón blanco”), PHA-0600 (“faba”), PHA-0609 (“planchada”) and PHA-0616 (“faba”). The immature grains of "caparrón blanco" landraces are traditionally consumed in the North of Spain being normally small-scale produced that means an opportunity for direct market farmers. Other good landraces in Vitoria were PHA-0331 (“caparrón”), PHA-0419 (“planchada”) and PHA-0330 (“faba”) originated in the Atlantic dominion.

Conclusion

Wide adaptation to different environments of common bean landraces displaying acceptable agronomic value and high seed quality is derived from this study. The stability across environments of some traits affecting yield and seed quality indicated that sucessful breeding should be conducted in this germplasm in different biogeographic dominions. A limited plasticity of some landraces is derived from this research. Two Mediterranean landraces in the Atlantic dominion and three Atlantic landraces in the Mediterranean dominion landraces had good agronomic performance. Under intermediate conditions some landraces were good performers, including some extra-large seeded ones. There are some landraces with aggressive climbing growth habit (type IV) that showed a good performance across the three environments. Indeterminate climbing types could have a yield compensation capacity to recover rapidly from stress conditions during their growing cycle.

Voysest (2000) reported few extra-large seeded types as "faba", "canario bola", "bolón rojo" and "mortiño" with 100-seeds weight over 70 g. In contrast, Santalla et al. (2002, 2004) found many types of Spanish beans such as "alubia", "faba", great northern, white kidney, "caparrón", "faba pinta", "pinta", "azufrado" and "palmeña" having extra large seeds. Additionally, Rodiño et al. (2003) reported a maximun seed weight of 119 g 100 seeds^{-1} and an average of 41 g 100 seeds^{-1} in a Spanish collection of bean germplasm. Therefore, some Spanish landraces deserve attention since they should be the largest source of variation for the genetic improvement of large and extra-large white-seeded bean varieties world-wide. Additionally, on the base of their quality and low input needs, some traditional landraces are currently cropped in organic farming according to the European guidelines (European Commission 2003).

As a conclusion, a valuable bean germplasm is on the farmer’s hand after centuries on unconscious on-farm phenotypic selection to preserve their own heritage such as the dry bean heirloom varieties. These landraces should be a useful germplasm for sustainable farming systems in different biogeographical areas and a valuable resource as parents in the genetic improvement of agronomical value and seed quality in dry bean.

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Table 1. Sources of the bean accessions evaluated

Source	Number of landraces
MBG - CSIC. Pontevedra, Spain. Collecting missions: 1988, 1993	47
CRF-INIA. Alcalá de Henares, Spain. National gene bank	13
SERIDA. Villaviciosa, Spain. Regional agricultural services	4
ITA. Valladolid, Spain. Regional agricultural services	2
ESAB. University of Barcelona. Barcelona, Spain	1
Envasadora Agrícola Leonesa. León, Spain. Seed traders	15
Exportadora Bañezana. La Bañeza, Spain. Seed traders	4
Cooperativa Tormes. El Barco de Ávila, Spain. Seed traders	3
Other, Spain	6

Table 2. Bio-geographic dominion and origin, landraces code, growth habit and seed type and name of the common bean accessions

Dominion/ Origin	Landrace code	Growth habit[1]	Seed colour	Seed shape[2]	Seed weight[3]	Local / commercial name[4]
1 - Atlantic[5] : bean surface: 3280 ha (sole crop),6761 ha (intercropped with maize)						
GALICIA	PHA-0006	I	purple mottled	C	52	Palmeña *
	PHA-0019	III	white	O	49	Garbancillo *
	PHA-0021	II	white	K	64	Riñón corto
	PHA-0029	III	white	O	34	Garbancillo *
	PHA-0112	IV	dark yellow	C	69	Azufrado
	PHA-0118	I	light red	K	61	Canela
	PHA-0124	I	light red	K	60	Riñón rosado
	PHA-0129	I	light red	K	59	Canela
	PHA-0131	I	red mottled	K	45	Pinta
	PHA-0168	I	light red	K	55	Sargaço
	PHA-0174	II	white	K	66	Alubia
	PHA-0181	III	white	K	64	Planchada
	PHA-0185	IV	white	K	78	Riñón
	PHA-0192	IV	black	R	51	Faba negra *
	PHA-0193	IV	dark red	C	71	Garbanzo oscuro *
	PHA-0197	IV	black	O	49	Negro redondo
	PHA-0199	I	white	R	56	Faba redonda *
	PHA-0212	IV	brown	R	55	Garbanzo oscuro *
	PHA-0226	IV	white	O	40	Planchada
	PHA-0230	IV	light red	K	76	Garbanzo oscuro *
	PHA-0240	I	white	K	51	Riñón
	PHA-0242	II	red mottled	R	65	Pinta
	PHA-0255	IV	white	K	79	Riñón
	PHA-0257	I	white	K	67	Riñón
	PHA-0264	III	white	O	33	Garbanzo *
	PHA-0267	I	white	K	70	Riñón
	PHA-0272	IV	white purple	O	44	Caparrón *
	PHA-0294	IV	white	C	54	Planchada
	PHA-0300	IV	light red	K	72	Riñón rojo
	PHA-0306	II	dark red	K	56	Garbanzo oscuro *
	PHA-0324	III	white	K	71	Riñón
	PHA-0339	I	white	K	42	Riñón
	PHA-0341	II	white	K	78	Alubia
	PHA-0392	I	light red	K	64	Canela
	PHA-0419	IV	white	K	72	Planchada

Table 2. Continuation

Dominion/ Origin	Landrace code	Growth habit[1]	Seed colour	Seed shape[2]	Seed weight[3]	Local / commercial name[4]
	PHA-0452	IV	white	T	102	Faba *
	PHA-0453	IV	purple	O	74	Morada
ASTURIAS	PHA-0123	IV	white	T	99	Faba *
	PHA-0219	IV	white	T	111	Faba *
	PHA-0221	IV	white	T	70	Faba *
	PHA-0222	IV	white	T	103	Faba *
	PHA-0223	IV	white	T	92	Faba *
	PHA-0258	IV	white	T	107	Faba *
	PHA-0329	II	black	O	22	Chicho negro *
	PHA-0330	IV	white	T	89	Faba *
	PHA-0331	IV	white purple	R	63	Virgen or caparrón *
	PHA-0333	IV	white	T	79	Faba *
	PHA-0396	IV	white	T	100	Faba *
	PHA-0397	II	black	O	21	Chicho negro *
	PHA-0404	I	white purple	O	65	Caparrón *
	PHA-0413	I	white purple	K	91	Faba pinta *
	PHA-0450	II	green	C	72	Verdina *
CANTABRIA	PHA-0271	IV	beige	R	51	Redonda *
	PHA-0376	IV	white	O	29	Chicho blanco *
	PHA-0380	IV	yellow	R	49	Chicho amarillo *
	PHA-0381	IV	white	O	33	Chicho blanco *
	PHA-0382	IV	beige	O	65	Azufrado
	PHA-0385	IV	white purple	R	58	Virgen or caparrón *
PAÍS VASCO	PHA-0630	IV	black	O	47	Tolosana *
	PHA-0631	I	purple beige	O	36	Guernikesa *
2 - Mediterranean[5]: bean surface: 7233 ha (sole crop), 92 ha (intercropped with maize)						
ANDALUCIA	PHA-0508	I	white	O	47	Riñón
	PHA-0511	I	white	C	52	Planchada
ARAGÓN	PHA-0633	IV	white	O	51	Blanca
	PHA-0635	IV	white	K	43	Del terreno or riñón
CASTILLA LA MANCHA	PHA-0536	I	white	C	52	Tronchera or alubia
CASTILLA Y LEÓN	PHA-0595	I	white	R	58	Bolita **
	PHA-0596	IV	red mottled	R	62	Cárdeno **
	PHA-0597	IV	light red	O	63	Dorada de Aragón **
	PHA-0598	III	yellow	O	35	De aceite **
	PHA-0599	IV	red mottled	R	68	Pinta

Table 2. Continuation

Dominion/ Origin	Landrace code	Growth habit[1]	Seed colour	Seed shape[2]	Seed weight[3]	Local / commercial name[4]
	PHA-0600	II	white	K	100	Faba *
	PHA-0601	I	purple beige	C	50	Palmeña *
	PHA-0602	IV	dark red	K	64	Rabona or riñón**
	PHA-0604	IV	beige	C	69	Del oro **
	PHA-0607	II	white	R	49	Redonda manteca **
	PHA-0608	IV	white purple	R	60	Virgen or caparrón *
	PHA-0609	IV	white	T	69	Planchada
	PHA-0610	IV	white	C	53	Plancheta
	PHA-0612	IV	light red	C	65	Iluro **
	PHA-0613	I	white	C	57	Blanca larga **
	PHA-0615	I	light red	K	61	Canela
	PHA-0616	IV	white	T	123	Faba *
	PHA-0617	I	white	R	48	Redonda
	PHA-0618	I	white	C	62	Alubia
	PHA-0619	I	white	C	57	Riñón
	PHA-0620	IV	red mottled	O	64	Pinta
	PHA-0643	III	white	R	54	Manteca de Gredos **
	PHA-0644	I	white	K	65	Riñón **
	PHA-0646	I	purple	K	60	Morada larga **
CATALUÑA	PHA-0623	IV	white	H	46	Ganxet *
	PHA-0637	I	white	O	27	Tabella brisa **
NAVARRA	PHA-0425	IV	black	O	49	Tolosana *
	PHA-0569	IV	white	O	41	Caparrón blanco *
VALENCIA	PHA-0581	I	white	K	60	Riñón
	PHA-0628	I	white	K	50	Tronquet *

[1] Growth habit: I-determinate, II-indeterminate upright, III- indeterminate prostrate, IV-indeterminate climbing

[2] Seed shape: C (Cuboid); H (Hook); K (Kidney); O (Oval); R (Round); T (Truncate)

[3] * Heirloom varieties: Spanish local name; ** Commercial name

[4] Seed weight: g 100 seeds^{-1}

[5] MAPYA 2001

Table 3. Mean squares of the analysis of variance, range of variation, mean, standard error, range of variation and coefficient of variation of the traits evaluated in the bean accessions

Source of variation	df[1]	Begining of flowering (days)		End of flowering (days)		Physiological maturity (days)		Seeds pod^{-1}		Pods $plant^{-1}$		Yield (g $plant^{-1}$)	
Environments (E)	2	23917.5	**	48718.3	**	112880.0	**	5.76		2881.5	**	31992.8	**
Replications /E	3	22.0		97.7	*	89.6		0.96		69.4		1155.2	
Landraces (L)	94	264.1	**	420.9	**	940.8	**	5.04	**	282.3	**	3453.3	**
L x E	188	18.6	**	75.9	**	167.7	**	0.50		110.6	**	1501.6	**
Error	282	8.8		28.1		64.8		0.42		53.0		754.6	
Maximun		93.5		124.5		187.0		8.80		60.0		262.6	
Minimun		37.5		58.0		88.0		2.70		9.3		13.5	
Mean		60.6		90.4		134.9		4.97		25.1		73.1	
SE[2]		1.7		3.06		4.7		0.37		4.2		15.9	
CV[3]		4.9		5.9		6.0		12.99		29.0		37.6	

[1] df: degrees of freedom

[2] SE: standard error

[3] CV: coefficient of variation

Table 3. Continuation

Source of variation	df[1]	Seed length (mm)	Seed widht (mm)	Seed thickness (mm)	Seed length/widht	Seed width/thickness	Seed weigth (g 100 seeds^{-1})	Seed water absorption (%)	Seed coat proportion (%)
Environments (E)	2	6.90 **	4.76 **	2.81 **	0.048 **	0.0013	834.5	0.303	19.74 **
Replications / E	3	0.11	0.08	0.13	0.003	0.0007	118.4 *	0.146 **	0.82
Landraces (L)	94	57.34 **	3.78 **	3.37 **	0.581 **	0.1203 **	2258.2 **	0.167 **	2.80 **
L x E	188	0.92 **	0.22 **	0.15 **	0.006 **	0.0056 **	201.5 **	0.012	1.62 **
Error	282	0.53	0.10	0.08	0.003	0.0033	32.8	0.013	1.11
Maximun		21.35	10.45	8.30	2.420	1.9550	194.2	1.380	13.49
Minimun		7.80	5.40	4.10	1.130	1.0900	20.5	0.160	3.98
Mean		14.41	8.25	6.33	1.745	1.3138	61.4	0.965	7.19
SE[2]		0.42	0.19	0.16	0.034	0.0329	3.3	0.066	0.60
CV[3]		5.04	3.90	4.50	3.333	4.3412	9.3	11.834	14.62

[1] df: degrees of freedom

[2] SE: standard error

[3] CV: coefficient of variation

Figure 1. Atlantic (1) and Mediterranean (2) biogeographic dominions in the Iberian Peninsula. Average rainfall, mean temperature and average bean yield are indicated for some areas (LA: Lalín, PO: Pontevedra, VI: Vitoria)

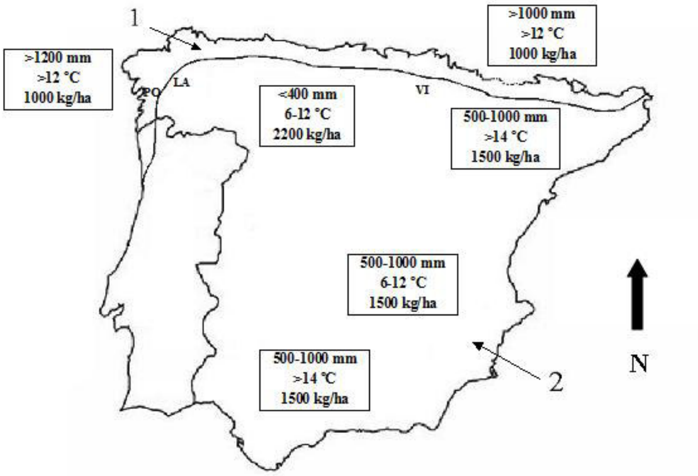
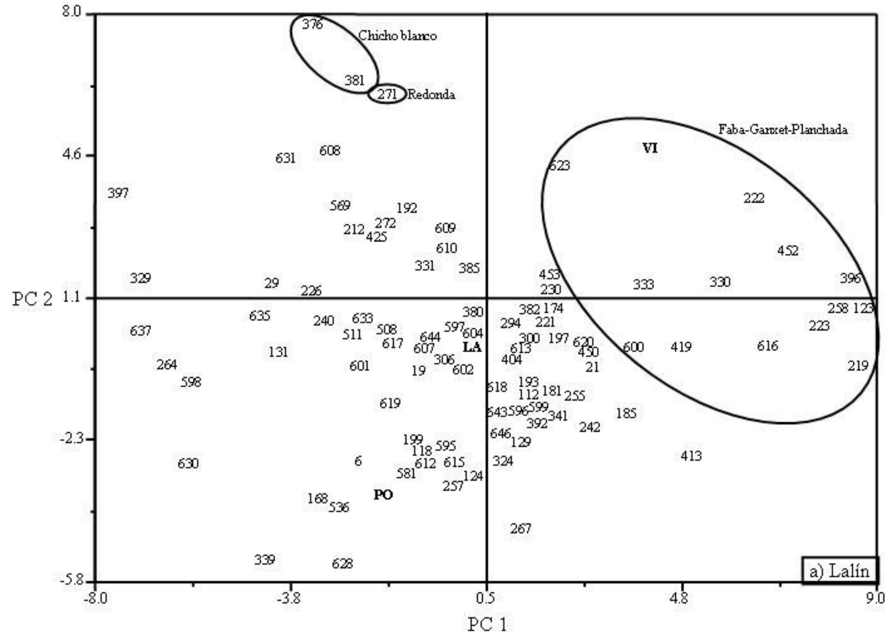
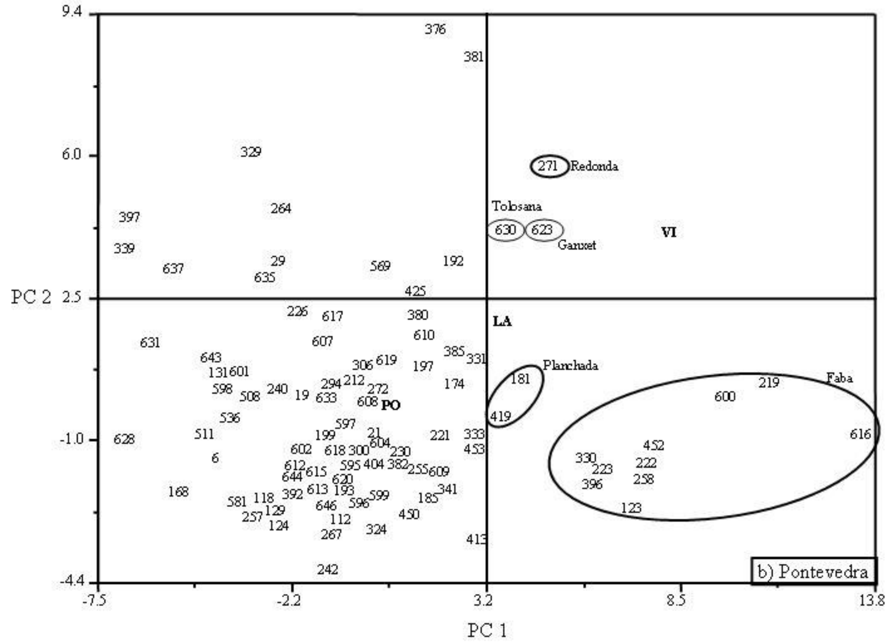
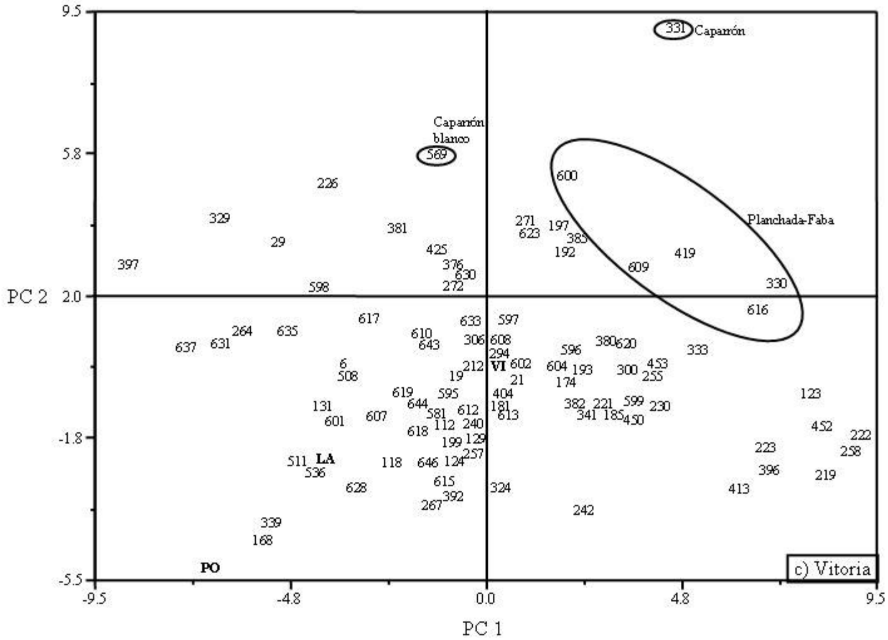


Figure 2. Distribution of the studied landraces along the axis representing the first (PC 1) and second (PC 2) principal components (numbers plus PHA- represent the code of the landraces; LA, PO, VI represents the averages for these environments): a) Lalín, b) Pontevedra, c) Vitoria. The ordination of some well-known landraces ("Chicho blanco", "Redonda", "Faba", "Ganxet", "Planchada", "Tolosana", "Caparrón", "Caparrón blanco") is enhanced.





9.4
6.0
2.5
-1.0
-4.4
PC 2
-7.5
-2.2
3.2
8.5
13.8
PC 1
376
381
329
264
397
339
637
29
635
569
192
425
271
Redonda
Tolosana
630
623
Ganxet
VI
LA
226
617
380
631
607
610
643
131601
598
508
240
19
294
212
633
306
619
272
608
197
385
331
174
Planchada
181
419
Faba
219
600
PO
536
597
511
628
199
21
604
221
333
453
602
618
300
230
6
612
644
615
595
404
382
255
609
620
168
581
118
392
613
193
599
185
341
129
257
124
646
596
112
450
324
267
413
242
616
452
330
223
222
396
258
123
b) Pontevedra



Caparrón
Caparrón blanco
Planchada-Faba
PC 2
PC 1
c) Vitoria
VI
LA
PO