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Characteristics of a common bean landrace (*Phaseolus vulgaris* L) of great culinary value and selection of a commercial inbred line

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Abstract: The Ganxet bean is a landrace that is greatly appreciated in northeast Spain. For commercial purposes a pure line selection process was undertaken in this landrace. Simultaneously, the Ganxet bean was compared with standard controls for nutritional traits. Seven inbred lines, representative of the variability within the Ganxet germplasm, were studied *per se* and compared with bean varieties White Kidney, Navy, Faba Asturiana and Tolosa. The Ganxet germplasm was found to contain more protein, less total dietary fibre, more digestible dietary fibre, a higher proportion of seedcoat, more glucose and less starch than the controls. Study of the agronomic, commercial, nutritional and gastronomic aspects of the Ganxet inbred lines showed sufficient variability to allow two inbred lines representative of Ganxet germplasm to be chosen for commercialisation.

Keywords: *Phaseolus vulgaris*; common bean; Ganxet bean; inbred lines; culinary quality; landrace; selection

INTRODUCTION

The Ganxet bean is a landrace cultivated in the northeast of the Iberian peninsula. It has a markedly hooked shape ('ganxet' means little hook in Catalan). Its culinary qualities, especially the tenderness of its seedcoat and its buttery texture, have allowed it to withstand competition from other varieties and ensured its high market value. It is a bean of indeterminate growth habit, with long internodes, dark green leaves and pods, white flowers, low yields, and it is eaten as a cooked dried legume. Its seeds are white and of medium-large size. An earlier study[1] of the populations commercialised as Ganxet beans, encompassing the entire region where cultivated, concluded that this bean probably reached the Catalan coast from America in the 19th century. Over time, crosses with other varieties have arisen, and many transitional forms between Ganxet and non-Ganxet beans are currently found.

In order to obtain homogeneous material that can be protected to guarantee the quality of the product reaching the consumer, a selection process was applied using samples from the entire region in which Ganxet is cultivated to recover the supposed ancestral form and study its traits.[1] Seven inbred lines were chosen from this selection process. All were markedly hook shaped (the most emblematic trait of the landrace), yet different from one another in agronomic and/or chemical traits. The chemical, gastronomic and nutritional characteristics of legumes show great variability because they are determined by genotype but are very strongly influenced by location and growing conditions. This makes it difficult to compare the results of different studies reported in the literature (data summarized by Kadam et al[2]). For parameters such as dietary fibre, the method of analysis can be another very important source of variation;[3] in this case, variation can be so great as to only allow comparisons drawn from a single experiment.

This study was conducted to: (a) compare the nutritional traits of the Ganxet material with other varieties of bean that are highly appreciated for their gastronomic qualities; (b) to determine the differences in morphology, agronomic characteristics and nutritional value among seven Ganxet inbred lines representing the variability within the prototypical Ganxet germplasm.

MATERIAL AND METHODS

Plant material

Bean populations labelled as Ganxet were exhaustively sampled in Catalonia. A pure line selection

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method was applied within and among the 46 collected Ganxet entries to achieve an enhanced hooked shape of the seed. In more advanced phases of the selection process, agronomic, morphological and culinary traits were considered. The seven pure lines obtained, all having very accentuated Ganxet traits but with differences between them,[4] were used in this study. The well-known bean standard types White Kidney (WK) and Navy, together with Tolosa (Tol) and Faba Asturiana (Fab), of great commercial importance in the region, were also used.

Experimental design

The different materials were sown in a randomized complete-block design, with three blocks at two locations (Castellar del Vallès and Caldes de Montbui) differing mainly in soil type. Each plot (material into block and location) consisted of 16 plants in a 1.75 m row. The distance between hills was 0.25 m, with two plants per hill. The distance between rows was 1.25 m. The Ganxet plants (of indeterminate growth habit) were supported by a vertical plastic net upheld by posts and tension cables placed along each row. White Kidney and Navy beans, having determinate growth, were sown in plots separated from the rest of the material of indeterminate growth habit by margins.

Traits studied

The following variables were recorded for each plot:

(1) Relative earliness of each variety. The earliest varieties were assigned a value of 1 and the latest a value of 3.
(2) Severity of *Alternaria* spp (0, total absence; 1, 5% of the surface affected; 2, 20%; 3, 50%).
(3) *Uromyces appendiculatus* and *Colletotrichum lindemuthianum* symptoms (0, total absence; 1, 5% of the surface affected; 2, 20%; 3, 50%).
(4) *Sclerotinia sclerotiorum* and Bean Common Mosaic Virus. Total number of plants affected.
(5) Length of the peduncle of the pod (cm), length of the pods (cm) and number of seeds per pod (recorded in a sample of 50 pods).
(6) Seed production and weight of 1000 seeds. Weight (g) of seeds after drying in forced air stove at 40°C to constant weight.
(7) Blemished seeds. Percentage of seeds rejected because of appearance (usually due to fungus or insects).
(8) Seed shape (1, slightly hooked; 3, very hooked) and commercial value based on seed appearance taking account of uniformity, colour, glossiness etc (1, low commercial value; 3, high commercial value). All seeds were assessed by three independent observers.

The seedcoats of 10 beans, chosen at random, were separated from the rest of the seed (endosperm plus embryo) after soaking for 6 h and dried to constant weight. The ratio seedcoat to total seed was calculated.

A random sample of 50 g of seeds was ground to pass a 0.5 mm screen of a mill and the following analyses were performed on this material:

(1) Crude protein (CP) and protein soluble in hydrochloric acid and pepsin were determined using the Kjeldahl method, quantifying the amount of nitrogen by selective ammonium electrode and using a factor of 6.25 to estimate the protein content. To estimate the protein soluble in hydrochloric acid and pepsin, samples were previously placed in a solution of 0.02% pepsin in 0.075 M hydrochloric acid for 48 h at 40°C and the suspension was separated by centrifugation. The digestibility of the protein was calculated from proportion of soluble protein to CP.
(2) Total and insoluble dietary fibres were determined by means of the Englyst Fibrezym Colorimetry Kit of the Medical Research Council, Dunn Clinical Nutrition Centre, n 7367722. Soluble dietary fibre was determined by subtracting the insoluble dietary fibre from the total dietary fibre.
(3) Starch was determined through the UV-Method (Boeheringer Mannheim, n 207748).
(4) Sugars and organic acids (stachyose, D-fructose, D-glucose, lactose, maltose, D-raffinose, saccharose, D-xylose, citric acid, fumaric acid, DL-malic acid, oxalic acid, succinic acid) were determined by gas-liquid chromatography on HP5 L25m, 0.02 mm diameter and 5% stationary phase non-polar-type phenyl-methyl silicone (SF), injection 1 µl with SPLIT 1 : 30, helium mobile phase, injection temperature 230°C, detection temperature 330°C and temperature programme of 60°C up to 120°C at 16°C min^{-1}, up to 160°C at 6°C min^{-1}, up to 325°C at 6°C min^{-1}, with trimethylsilyl derivation reaction. This allowed the simultaneous determination of sugars and acids.
(5) Content of ash recorded after incinerating at 550°C to constant weight.[5]
(6) Sensory analyses were performed on a homogeneous sample of each Ganxet inbred line. The samples were soaked for 12 h at 30°C and cooked at 100°C for 1 h. Neither salt nor other additives were used. Samples were assessed for taste, texture and other traits related to culinary value (0, poor quality; 3, excellent quality). Five independent observers evaluated samples of the seven Ganxet inbred lines on the following characteristics: seedcoat perception; texture; taste; appearance; degree of hook of the cooked bean.

Statistical analysis

The data for each trait were studied by means of ANOVA using the SAS statistical package[6] according to a linear model that considered the effects of material, location, block into location and inter-

actions. For sensory analysis, seeds of each Ganxet inbred line were pooled after homogeneity testing, obtaining a unique sample per line. The data were studied by means of ANOVA using the above-mentioned statistical package according to a linear model that considered the effects inbred line and evaluator.

RESULTS AND DISCUSSION

Ganxet beans with respect to other beans

The Ganxet beans had higher CP (283.3 g kg^{-1}) than the controls (Table 1). Only Navy was not significantly different from the mean of the Ganxet values. Tolosa had lower CP (218.8 g kg^{-1}) than all seven Ganxet inbred lines. The Ganxet landrace had a higher proportion of CP in comparison with the other varieties and with values published for a wide range of material. The CP content of the Ganxet inbred lines is high in comparison with the protein content described in FAO and USDHEW[7] and Deutsche Forschungsanstal für Lebensmittelchemie.[8] Vazquez and Cardenas[9] reported values of 230–270 g kg^{-1} in South American varieties and 210–250 g kg^{-1} in Mexican material. Fueyo et al[10] found 240–260 g kg^{-1} CP in different populations of Faba Asturiana, and 220–270 g kg^{-1} was found in a wide range of samples from Northwestern Spain.[11] Our results corroborate the high proportion of protein found for Ganxet germplasm reported by MAPA.[12] The digestibility of the protein found in the Ganxet inbred lines (870.1 g kg^{-1}) was not significantly different from the controls, except for Tolosa, which had a lower digestible protein content (Table 1). The digestibility of protein in Ganxet, White Kidney and Faba is especially high compared with the review by Barampama and Simard.[13]

The Ganxet inbred lines had less total dietary fibre (225.7 g kg^{-1}) than the controls (Table 1). White Kidney and Tolosa had a higher proportion of total dietary fibre than all the Ganxet inbred lines. Kidney beans had higher values for total dietary fibre than Lima beans[14] and than other varieties such as Great Northern, large Lima, Navy, Pink, or Pinto.[15] A high proportion of total dietary fibre for Kidney beans (closely followed by Navy) was later corroborated by Li[16] in a wider range of varieties. A study of the black Mexican bean showed much lower contents of soluble dietary fibre (35 g kg^{-1}) than the Ganxet inbred lines and less total dietary fibre (203 g kg^{-1}).[17] Mongeau and Brassard[3] also reported lower values of soluble dietary fibre for White Kidney than for Great Northern. The mean content of soluble dietary fibre of the Ganxet inbred lines (102.2 g kg^{-1}) was higher than all the controls except Navy (Table 1). As a consequence, the proportion of soluble dietary fibre to total dietary fibre of the controls was lower than the mean value for all the Ganxet inbred lines (0.452). Indeed, Faba, White Kidney and Tolosa were surpassed by all seven Ganxet inbred lines for this trait (Table 1).

The four controls had a higher proportion of starch than the mean of the Ganxet inbred lines (255.1 g kg^{-1}) (Table 1). Faba, White Kidney and Tolosa had a higher proportion of starch than the Ganxet inbred line with the highest starch content (275.0 g kg^{-1}). Santalla *et al*[11] found a high degree of variability (298.0–464.4 g kg^{-1}) for starch content in a group of populations and controls in the northwest of the Iberian peninsula.

Table 1. Mean values of nutritional traits (in g kg^{-1} except ratios) for each Ganxet inbred line[a] and controls[b], together with the least significant difference (lsd) when differences between materials were found in the ANOVA ($p \leq 0.05$)[c]

	L64	*L67*	*L23*	*L27*	***Gan***	*L19*	*L44*	*L5*	*Navy*	*Fab*	*WK*	*Tol*	*lsd*
Crude protein	296.4	293.2	288.4	285.9	**283.3**	281.4	271.4	266.9	265.9	265.0	256.1	218.8	17.9
Soluble protein	246.8	255.7	256.2	250.0	**247.0**	246.1	237.3	237.0	231.7	233.6	227.3	180.9	18.7
Protein digestibility	813.3	873.4	889.7	872.9	**870.1**	876.5	876.1	889.3	872.4	880.9	887.0	823.2	35.2
Dietary fibre	217.7	220.6	223.6	223.4	**225.7**	227.8	234.1	233.2	235.5	231.9	237.1	245.9	02.3
Insoluble dietary fibre	116.9	116.3	122.2	123.2	**123.4**	125.6	130.2	129.8	131.0	133.5	136.6	156.1	01.3
Soluble dietary fibre	100.8	104.3	101.4	100.2	**102.2**	102.1	103.8	103.4	104.4	98.3	100.5	89.8	01.0
Soluble dietary fibre/dietary fibre	0.462	0.472	0.452	0.447	**0.452**	0.447	0.442	0.442	0.442	0.423	0.423	0.364	0.002
Saccharose	11.22	21.22	21.80	21.57	**21.14**	20.60	20.40	21.22	17.67	25.25	17.65	24.75	02.5
Glucose	0.75	0.82	0.77	0.70	**0.74**	0.75	0.67	0.72	0.52	0.47	0.27	0.50	0.14
Starch	247.2	250.7	252.5	245.4	**255.1**	250.1	265.2	275.0	279.9	296.8	304.2	323.2	11.3
Raffinose	2.52	2.60	2.13	2.75	**2.49**	2.47	2.60	2.40	4.02	2.27	1.95	1.17	0.53
Stachyose	19.52	20.22	19.45	20.05	**19.54**	19.32	19.32	18.92	21.05	20.40	18.23	18.15	NS
Fructose	0.09	0.11	0.06	0.10	**0.08**	0.08	0.10	0.07	0.05	0.05	0.03	0.09	NS
Succinic acid	0.12	0.12	0.10	0.10	**0.13**	0.18	0.12	0.20	0.09	0.22	0.06	0.07	NS
Fumaric acid	0.09	0.11	0.06	0.04	**0.13**	0.17	0.08	0.15	0.10	0.12	0.12	0.15	NS
Citric acid	10.37	10.22	11.07	8.95	**10.51**	10.85	9.10	13.07	11.72	11.20	14.02	16.30	NS
Malic acid	0.32	0.32	0.25	0.27	**0.31**	0.35	0.27	0.40	0.17	0.42	0.15	0.17	0.10
Ash	39.2	38.8	42.0	40.9	**40.9**	41.0	42.3	42.5	43.7	46.0	40.8	40.0	NS
Seedcoat/total seed	0.092	0.093	0.096	0.089	**0.092**	0.089	0.094	0.089	0.073	0.074	0.073	0.079	0.005

[a] Gan, mean of all Ganxet inbred lines included in the study
[b] Navy, Navy; Fab, Faba Asturiana; WK, White Kidney; Tol, Tolosa
[c] NS, not significant $p \leq 0.05$

Table 2. Mean values for morphological and agronomic traits for each Ganxet inbred line, together with the least significant difference (lsd) when differences between genotypes were detected in the ANOVA ($p \leq 0.05$)[a]

	L44	*L27*	*L23*	*L64*	*L67*	*L5*	*L19*	*lsd*
Production[b]	1055	1015	1004	1000	973	964	923	NS
% blemished seeds	2.98	2.58	1.66	3.04	2.93	3.95	3.34	NS
1000 seeds weight	503	507	506	503	523	510	517	NS
Pod length[c]	14.7	14.9	15.7	15.2	15.1	14.8	15.0	NS
Seeds per pod	4.48	4.22	4.59	4.04	4.38	3.97	4.17	0.38
Peduncle length[c]	11.98	12.60	11.68	12.78	12.55	12.24	12.54	NS
Earliness	2.17	2.50	2.10	1.83	2.00	2.50	1.33	0.75
Hook degree	2.28	2.42	2.31	2.78	2.75	2.08	2.89	0.16
Alternaria	1.00	1.17	1.17	1.42	0.75	0.92	1.25	NS
Uromyces	0.75	0.33	0.58	0.25	0.38	0.33	0.17	NS
Colletotrichum	0.67	0.75	0.42	0.50	0.38	0.17	0.33	NS
Sclerotinia	0.00	0.50	0.33	0.17	0.00	0.17	0.50	NS
Bean Common Mosaic Virus	0.33	0.17	0.17	0.17	0.25	0.17	0.33	NS
Commercial value	2.14	2.19	2.58	2.28	2.46	2.31	2.44	0.22

[a] NS, not significant $p \leq 0.05$
[b] In g per plot
[c] In cm

The Ganxet inbred lines had higher sucrose concentration (21.14 g kg^{-1}) than Navy and White Kidney (Table 1), but Faba and Tolosa had higher sucrose than the Ganxet inbred line with the highest sucrose content (21.80 g kg^{-1}) (Table 1). All the controls had less glucose than the mean of the Ganxet samples (0.74 g kg^{-1}). Indeed, even the Ganxet inbred line with the lowest glucose content surpassed all the controls (Table 1). Navy bean had more raffinose than all of the Ganxet inbred lines (Table 1). The mean of the Ganxet inbred lines (2.49 g kg^{-1}) was higher than Tolosa and White Kidney (Table 1). Tolosa had less raffinose than the Ganxet inbred line with the lowest percentage of raffinose (Table 1). The oligosaccharides of the raffinose family (raffinose, verbascose, ajugose) had been identified as one of most important causes of flatulence,[18–20] although other factors are also important.[21,22] Reddy *et al*[23] found no differences in the concentrations of sugars of the raffinose family between Red Kidney, Navy and Pinto. No significant differences were found between the Ganxet inbred lines and the controls for stachyose or fructose (Table 1).

No significant differences were found between the Ganxet inbred lines and the controls for succinic, fumaric or citric acids (Table 1). On the other hand, Navy, White Kidney and Tolosa had lower values than the mean of the Ganxet inbred lines (0.31 g kg^{-1}) for malic acid (Table 1). The Faba had more malic acid than the mean of the Ganxet inbred lines, but not more than the Ganxet inbred line with the highest value (Table 1).

No significant differences were found between the Ganxet inbred lines and the controls for ash content (Table 1).

The four controls had a lower ratio of seedcoat weight to total seed weight than the mean value for the seven Ganxet inbred lines, and lower than the Ganxet inbred line with the lowest value for this trait (Table 1). This result seems contradictory to the sensory perception of the Ganxet beans which is considered by consumers to have less seedcoat than the controls. The pronounced hook shape of the Ganxet favours a larger ratio of surface to volume and thus a high proportion of seedcoat; however, Navy beans, being smaller, would also be affected by a similarly high ratio. Thus the low perception of seedcoat in the Ganxet beans might be due more to the chemical components of the seedcoat than to its proportion.

There seem to be clear differences in chemical composition between the Ganxet bean and the controls. Even White Kidney, which has a similar though not so pronounced hooked-shape appearance,[24] was different from Ganxet. The most highly regarded beans (Ganxet, Faba, Tolosa) are those that contain a higher proportion of sucrose, which makes them sweeter, although Tolosa has a more floury texture due to its lower content of protein and higher content of starch.

Variability of the Ganxet populations

A study of the morphology and susceptibility to disease of the seven inbred lines (representative of the main types classified as typical Ganxet)[4] was carried out to complement the study of their chemical characteristics.

The agronomic traits for which significant differences were found between the inbred lines were earliness, number of seeds per pod and degree of hook. Even considering that all the material had very hook-shaped seeds, the inbred lines L19, L64 and L67 showed values for this trait close to the maximum recorded in the landrace (Table 2).[24] No significant differences between inbred lines were found regarding susceptibility to disease (Table 2). Significant differences were found for the estimated commercial value of the beans. The highest values for this estimate were found for L23, L67 and L19 (Table 2).

Values for the nutritional traits showed variation amongst the seven inbred lines studied (Table 1). The high contents of soluble protein, soluble dietary fibre, sucrose, glucose and malic acid were considered to be desirable, as were low levels of insoluble dietary fibre, starch, raffinose and seedcoat. The genotype having the most desirable traits overall was L67, followed by L64 and L19.

No significant differences in texture were found among the inbred lines, and only slight differences in taste were found (Table 3). Owing to the methodology of this analysis (much less technically developed than for other products such as wine and oil), the results obtained in this study are not considered to be conclusive, although they suggest that there is a certain degree of variability in the sensory perception of the material studied. Overall results are similar for all the inbred lines except L5, which was considered to be inferior to the rest.

The study of the morphologic, agronomic and commercial aspects, together with the nutritional and sensory-perceptual aspects, shows there is variability among the seven inbred lines. The apparent correspondence between enhanced Ganxet morphology and superior nutritional quality of the materials is noteworthy.

The majority of chemical traits considered determinants of nutritional value are subject to strong environmental influences. Of the 19 traits studied, 11 showed a significant effect for location, 9 showed a significant block effect, and 8 had a significant genotype × location interaction (Table 4). This means that data reported in the literature can only provide a frame of reference, and comparisons are only reasonable in the case of data collected from a single experiment. The agronomic and commercial traits (only studied in the Ganxet landrace) are also subject to strong environmental influence. Of the 14 traits studied, 9 showed a significant location effect (pod length, seeds per pod, peduncle length, hook degree, *Alternaria*, *Colletotrichum*, *Sclerotinia*, Bean Common Mosaic Virus and commercial value). Unlike the nutritional traits, however, none of the agronomic traits showed a significant genotype × location interaction. The strong genotype × location interaction for most nutritional traits

Table 3. Results of the sensory analysis and assessment of degree of hook in the cooked beans for each Ganxet inbred line[a], together with the least significant difference (lsd) when differences between genotypes were found in the ANOVA ($p \leq 0.05$)[b]

Sample	*Tenderness of seedcoat*	*Texture*	*Taste*	*Appearance*	*Hook*	*Accumulated*
L5	2.1	2.1	2.1	1.8	1.6	9.7
L19	2	2.1	2.2	2.1	2.6	11.0
L23	1.8	2	2.2	2	2.3	10.3
L27	2	2	2.4	2.2	2.4	11.0
L44	2.2	2.2	2.4	2.6	2	11.4
L64	1.5	1.8	1.9	2.7	3	10.9
L67	1.9	2.2	2.2	2.4	2.1	10.8
lsd	0.6	NS	0.3	0.7	0.7	1.0

[a] 0, minimum value; 3, maximum value, for all traits
[b] NS, not significant $p \leq 0.05$

Table 4. *F*-test significance of effects in the ANOVA of the nutritional traits[a]

	Material	*Location*	*Block*	*Material × location*
Crude protein	0.0001	0.0001	0.0001	NS
Soluble protein	0.0001	0.0002	0.0001	NS
Protein digestibility	0.001	0.01	NS	0.002
Dietary fibre	0.0001	0.0001	0.0001	0.0001
Insoluble dietary fibre	0.0001	0.0001	0.0001	0.0001
Soluble dietary fibe	0.0001	0.0001	0.001	0.0001
Soluble dietary fibre/dietary fibre	0.0001	NS	0.0001	NS
Saccharose	0.0001	0.0009	NS	0.0043
Glucose	0.0001	0.0001	0.01	0.01
Starch	0.0001	NS	NS	NS
Raffinose	0.0001	NS	NS	0.0003
Stachyose	NS	NS	0.006	0.007
Fructose	NS	NS	NS	NS
Succinic acid	NS	NS	NS	NS
Fumaric acid	NS	NS	NS	NS
Citric acid	NS	NS	0.03	NS
Malic acid	0.0002	0.005	NS	NS
Ash	NS	0.009	NS	NS
Seedcoat/total seed	0.0001	0.0007	NS	NS

[a] NS, not significant $p \leq 0.05$

is relevant to selection as it makes selection in different environments desirable. Selection for agronomic traits would be simpler to organise.

In light of the results, the inbred line L67 was considered to have the most favourable characteristics to merit special protection and promotion for commercial use as a Ganxet brand, although L23 was also remarkable for its very high commercial value. Both inbred lines are being registered, and seeds are available from our laboratory.

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