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Evaluation of local onion lines from northwest Spain

A. Rivera Martínez, J. Fernández Paz and J. L. Andrés Ares*

Centro de Investigaciones Agrarias de Mabegondo.
Ctra. Betanzos-Santiago, km 7.5. 15318 Abegondo (A Coruña). Spain

Abstract

Traditional onion (*Allium cepa* L.) varieties are still produced in certain regions of Spain due to their high quality and acceptance in local markets. The evaluation of morphological traits for 18 local northwestern Spanish onion lines showed the existence of three different groups attending exclusively to bulb shape traits and six classes if we consider bulb shape traits as well as skin and flesh colours. There was a positive correlation between storage quality and percentage of dry matter content. The importance of considering well defined descriptors in order to characterize correctly onion germplasm is also discussed in this paper.

Additional key words: *Allium cepa*, characterization, dry matter, germplasm, storage quality.

Resumen

Evaluación de líneas locales de cebolla del noroeste español

En determinadas regiones españolas todavía se cultivan variedades tradicionales de cebolla (*Allium cepa* L.) debido a su elevada calidad organoléptica que hace que tengan una buena aceptación en determinados mercados locales. La evaluación morfológica de 18 cultivares de cebolla recopilados en el noroeste español ha permitido la caracterización de las mismas en tres grupos bien diferenciados si se consideran los caracteres relacionados con la forma del bulbo exclusivamente y seis clases si se tienen en consideración tanto la forma del bulbo como el color de la piel y de la carne. En las líneas estudiadas existe, asimismo, una correlación positiva entre la calidad de conservación y el porcentaje de materia seca. En el artículo se discute también la importancia del uso de descriptores bien definidos en las caracterizaciones de germoplasma de cebolla.

Palabras clave adicionales: *Allium cepa,* calidad de almacenamiento, caracterización, germoplasma, materia seca.

Introduction

Onions (*Allium cepa* L.) are cultivated all around the world. Among the great genetic variation, existing worldwide, certain genotypes can even complete their cycle in regions with short summers. In Spain, 900 ha of onion are located in the northwestern part of the country —the total Spanish onion growing area is 22,700 hectares— and it is considered as the fourth vegetable crop in Galicia (northwest Spain), according to either surface area or production (MAPA, 2002). It is mainly a traditional crop in this part of the country were there is an important number of local landraces with excellent organoleptic qualities.

The introduction of new varieties represents an important increase in the number of cultivars available for growers, which is not only an advantage for them but also for markets and processing industries. However, the traditional varieties are still produced in certain regions due to their high quality and acceptance at local and foreign markets (Casallo *et al*., 1991).

Evaluations of local onion lines have been carried out all over the world. Most of these characterizations are based either on morphological, agronomical or physical and chemical measurements. The chemical measurements most frequently used are soluble solids contents (Jitendra *et al*., 1992; Ashish *et al*., 1995; Llamazares *et al*., 2002), dry matter (Szalay, 1971; Szalay, 1981; Llamazares *et al*., 2002), piruvic acid (Vavrina and Smitle, 1993; Ashish *et al*., 1995; Duff *et al*., 2002; Llamazares *et al*., 2002) or sugar contents (Lai *et al*., 1994).

Another important criterion for onion bulb characterizations is storage quality. There are some morphological and chemical traits related to storage

* Corresponding author: jose.luis.andres.ares@xunta.es
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quality such as bulb size (Mattana and Lobo, 1980; Patil and Kale, 1985b; Rajapakse *et al*., 1992), dry matter (Mattana and Lobo, 1980), total soluble solids (Albert and Cuquerella, 1979; Patil and Kale, 1985a) or sugar contents (Patil and Kale, 1985a).

In 1998, the horticultural research group at the CIAM (*Centro de Investigaciones Agrarias de Mabegondo*) collected seeds of local onion varieties in the main productive regions in northwest Spain. As a result of this sampling, 20 onion lines are kept at the CIAM germplasm bank. This work presents the results obtained from the evaluation of morphological, agronomical and storage quality characters for 18 of these lines in comparison with four commercial varieties, frequently used by growers in this part of the country.

Material and Methods

Twenty-two lines of onion were evaluated in northwest Spain over four years from 1999 to 2002. The site is located at Mabegondo (43º 15'N, 8º 18'W) near the coast. Eighteen of the total number of lines corresponded to local onion landraces collected as seeds obtained by farmers in the main growing regions of northwest Spain (Table 1). The characterizations comprised morphological and agronomical measurements, carried out in 1999 and 2000, as well as a storage quality evaluation which took place in 2001 and 2002.

All of the lines as well as four commercial varieties were sown under greenhouse conditions, the seedlings were transplanted to the field in May and the harvest took place in September. The experimental design was a complete randomized block design with three replications for a total of 84 plants per plot (0.25 × 0.15 m).

The following measurements were recorded on 25 bulbs per landrace, which were randomly collected at the end of the experiment: bulb height (cm), diameter (cm), weight (g), and neck width (cm). The remaining parameters corresponding to bulb shape, skin colour, flesh colour and number of axes – were determined following the TG/46/6 UPOV (1999) guidelines.

In order to carry out the storage quality evaluations, 100 healthy, non sprouted, bulbs were collected randomly per line after harvest and stored in wooden boxes at 10-15ºC for the following 24 weeks. Every 4 weeks each line was evaluated counting and weighting the sprouted, rotted and healthy bulbs.

Table 1. Origin of the Spanish onion (*Allium cepa* L.) line under study

Genotype	Origin	Type of genotype	Type of evaluation
1. Ribadeo 1	Lugo	Local line	Mor, Yie, Sto
2. Ribadeo 2	Lugo	Local line	Mor, Yie, Sto
3. Betanzos	A Coruña	Local line	Mor, Yie, Sto
4. Ameixenda	A Coruña	Local line	Mor, Yie, Sto
5. S-Xulián	Lugo	Local line	Mor, Yie, Sto
6. Baldaio	A Coruña	Local line	Mor, Yie, Sto
7. Mondoñedo	Lugo	Local line	Mor, Yie, Sto
8. Chata-Miño	A Coruña	Local line	Mor, Yie, Sto
9. Oimbra	Ourense	Local line	Mor, Yie, Sto
10. Caldas	Pontevedra	Local line	Mor, Yie, Sto
11. Pontearnelas	Pontevedra	Local line	Mor
12. Vilagarcía 1	Pontevedra	Local line	Mor, Yie, Sto
13. Vilagarcía 2	Pontevedra	Local line	Mor, Yie, Sto
14. Outes	A Coruña	Local line	Mor, Yie, Sto
15. Arcade	Pontevedra	Local line	Mor, Yie, Sto
16. Ponteareas	Pontevedra	Local line	Mor, Yie, Sto
17. A Garda	Pontevedra	Local line	Mor
18. Cea	Ourense	Local line	Mor, Sto
19. Paja Virtudes	Spain	Commercial variety	Mor, Sto
20. Babosa	Spain	Commercial variety	Mor, Sto
21. Castillo	Spain	Commercial variety	Mor, Sto
22. Arctic	Spain	Commercial variety	Mor, Sto

Type of evaluation: Mor: morphological. Yie: yield. Sto: storage.

At the beginning of the storage experiments the percentage of dry matter was estimated for each of the studied lines: a representative 500 g sample was obtained mixing 20 slices cut from 20 bulbs randomly sampled from each line. The sample was then dried at 80ºC for a period of 48 h by means of a stove, calculating the percentage of dry matter as a relation between fresh and dry weights.

An analysis of variance of these morphological traits was carried out independently for each year of evaluation. The statistical model used for these data was the following (Cubero and Flores, 1995):

$$X_{ij} = M_u + g_j + E_{ijk}$$

where: M_u is the overall average, g_j is the line effect, and E_{ijk} is the residual effect.

Yield data from plots were analysed using the following model (Cubero and Flores, 1995):

$$X_{ij} = M_u + b_i + g_j + E_{ijk}$$

where: b_i is the block effect, and E_{ijk} is the residual (i.e. within plot) effect. The block effect was considered a random effect.

Multivariate relationships among lines were revealed with a principal component analysis (PCA) using a correlation matrix derived from the significant traits after the analysis of variance. Components with eigenvalues greater than one were used through hierarchical clustering analysis, based on Euclidean distance computed between each population. The dendogram formed by this method was cut at the third level cluster, each cluster being represented on the Principal Component Plan 1-2.

Regression analyses were performed to determine the influence of dry matter contents on storage quality (percentage of sprouted bulbs 24 weeks after harvest). Curves with the highest R^2 were chosen as best fit.

Results

Morphological characterization of the lines

There were certain characters with great variation between lines, i.e.: traits related to bulb size (height, diameter and shape) as well as skin colour (Table 2). The analysis of variance (ANOVA) for morphological quantitative characters showed highly significant differences between lines for all of the traits under study: bulb height, weight, diameter, height-diameter ratio and neck width (Table 3). According to these traits, the lines could be classified into three different groups by means of a PCA which absorbed 58% of the

Table 2. Bulb morphological description of 18 local onion lines from northwest Spain. 1999-2000

	Line	Weight (g)	Height H(cm)	Diameter D(cm)	Width of neck (mm)	D/H	Bulb shape	Skin colour	Flesh colour	Nax
1.	Ribadeo 1	123.1	5.1	6.8	8.8	1.3	R	Brown	Absent	Few
2.	Ribadeo 2	171	5.5	7.5	10.9	1.4	R	Brown	Absent	Very few
3.	Betanzos	124	3.9	7.4	8.4	1.9	TNE	Pale yellow	Absent	Very few
4.	Ameixenda	164.8	4.8	7.8	9.9	1.6	TE	Yellow-brown	Absent	Very few
5.	S. Xulián	114.4	3.8	7.2	9.7	1.9	TNE	Brown-red	Absent	Very few
6.	Baldaio	146.7	4.2	7.6	12.2	1.8	TNE	Yellow-brown	Absent	Very few
7.	Mondoñedo	122.1	4.1	7.3	11.1	1.8	TNE	Yellow-brown	Absent	Very few
8.	Chata-Miño	128.8	3.9	7.5	9.2	1.9	TNE	Brown	Absent	Very few
9.	Oimbra	170.2	5.5	7.6	11.4	1.4	R	Yellow-brown	Absent	Few
10.	Caldas	158	4.8	7.6	11.3	1.6	TE	Yellow-brown	Absent	Very few
11.	Pontearnelas	139.7	4	7.5	10	1.9	TNE	Brown	Absent	Very few
12.	Vilagarcía 1	158	5.4	7	11.5	1.3	R	Pale yellow	Absent	Very few
13.	Vilagarcia 2	134.1	4.7	7.1	11.5	1.5	TE-R	Pale yellow	Absent	Very few
14.	Outes	139.5	4.8	7.2	11.7	1.5	TE-R	Yellow-brown	Absent	Very few
15.	Arcade	155.4	4.6	7.6	11.4	1.6	TE	Pale yellow	Absent	Very few
16.	Ponteareas	145.6	4.3	7.7	12.1	1.8	TNE	Yellow-brown	Absent	Very few
17.	A Garda	158.7	4.5	7.9	11.3	1.8	TNE	Yellow-brown	Absent	Very few
18.	Cea	122.2	4.7	7	12.3	1.5	TE-R	Yellow-brown	Absent	Very few

The bulb characterization was carried out following TG/46/6 UPOV descriptors: D/H: diameter/height ratio. Bulb Shape: R-rhombic. TNE: transverse narrow elliptic. TE: transverse elliptic. Nax: number of axes.

Table 3. ANOVA for morphological quantitative characters on 18 local onion lines evaluated at Mabegondo (A Coruña) in 1999 and 2000

	Mean	Range	Lines
Bulb characters 1999			
Height-H (cm)	4.49	3.47-5.48	***
Diameter-D (cm)	7.28	6.39-7.87	***
Weight (g)	133.14	99.46-180.74	***
Index (H/D)	1.67	1.29-2.01	***
Neck width (cm)	1.08	8.44-12.34	***
Bulb characters 2000			
Height-H (cm)	4.70	3.84-5.81	***
Diameter-D (cm)	7.60	7.10-8.15	***
Weight (g)	153.49	114.92-195.93	***
Index (H/D)	1.65	1.32-1.92	***
Neck width (cm)	1.28	0.96-1.77	***

The yield results correspond with those of the experiment carried out on 2002. ***: significant at 0.001 level.

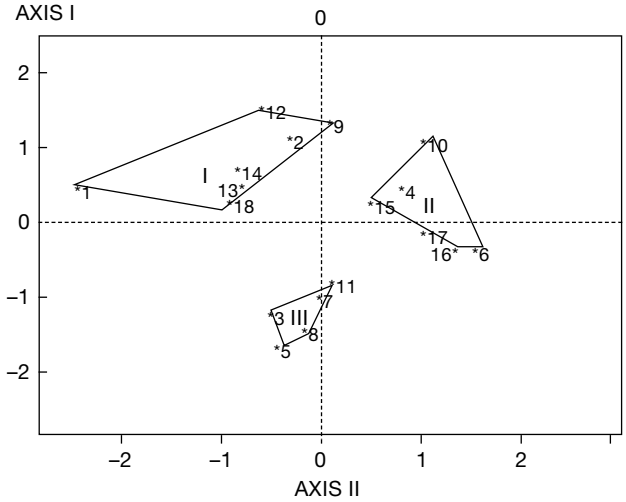

Figure 1. Projection of 18 local lines of *Allium cepa* L. on the plan 1-2 of a principal component analysis carried out on a correlation matrix on morphological traits. Accumulated variance = 58%.

accumulated variance (Fig. 1). These corresponded to: lines with rhombic bulb – such as 'Ribadeo', 'Oimbra', 'Vilagarcía', 'Outes' and 'Cea'-, with transverse narrow elliptic shape – 'Betanzos', 'S. Xulián', 'Mondoñedo', 'Chata-Miño' and 'Pontearnelas' – and lines with bulb shapes ranging from transverse elliptic to transverse narrow elliptic –'Ameixenda', 'Baldaio', 'Caldas', 'Arcade', 'Ponteareas' and 'A Garda'–. A Duncan's multiple range test was carried out on these traits between the three defined groups obtaining significant differences between the groups for all of the traits except for the neck width in 2000 (Table 4).

Table 4. Means of the different groups obtained from the ascendent hierarchical classification

Groups	I	II	III
Lines	1.2.9.12.13.14.18	4.6.10.15.16.17	3.5.7.8.11
Bulb quantitative characters (1999)			
Height-H (cm)	5.04 a	4.43 b	3.80 c
Diameter-D (cm)	7.05 c	7.61 a	7.23 b
Weight (g)	135.56 b	145.05 a	115.46 c
Index (H/D)	1.42 c	1.74 b	1.93 a
Neck width (cm)	1.140 a	1.114 a	0.968 b
Bulb quantitative characters (2000)			
Height-H (cm)	5.21 a	4.64 b	4.07 c
Diameter-D (cm)	7.43 b	7.89 a	7.49 b
Weight (g)	156.82 a	164.58 a	135.57 b
Index (H/D)	1.45 c	1.72 b	1.85 a
Neck width (cm)	1.229 a	1.338 a	1.280 a
Other morphological characters			
Skin colors	Brown-yellow	Yellow-brown	Brown-yellow
Shape	R	TE/TNE	TNE

Means in the same line followed by the same letter are not significantly different from each other based on Duncan's multiple range test at P = 0.05. Shape: R-rhombic. TNE: transverse narrow elliptic. TE: transverse elliptic.

Table 5. Local northwestern onion lines grouping attending to Castell and Díez (2000) criteria

Type[1]	Skin colour	Flesh colour	Subgroup[1]	Bulb shape		Studied lines
				Castell and Díez[1]	UPOV[2]	
Grain type[1]	Brown	White	4.1.1	Rounded	C/R[4]	
	Red	Purple	4.1.2	Rounded	C/R	
Viguetana type[1]	White	White	4.2.1	Elliptic/ovate	BE	
	Red	Purple	4.2.2	Rounded/elliptic	BE/C	
Red Storage type[1]	White	White	4.3.1	Oval	TE/TNE	
	Brown	White	4.3.2	Oval	TE/TNE	8. 11. 6. 7. 16. 17. 4. 10
	Brown	Purple	4.3.3	Oval	TE/TNE	
	Red	Pale purple	4.3.4	Oval	TE/TNE	5
Conical type[1]	Brown	White	4.4.1	Conical	R	1. 2. 9. 14. 18
	Purple	Purple	4.4.2	Conical	R	
Babosa type[1]	White	White	4.5.1	Inverted conical	BO	
	Brown	White	4.5.2	Inverted conical	BO	
	Brown	Purple	4.5.3	Inverted conical	BO	
Other types[3]	Pale yellow	White	—	Conical	R	12. 13
	Pale yellow	White	—	Oval	TNE	3
	Pale yellow	White	—	Oval	TE	15

[1] Onion groups, subgroups and bulb shape following Castell and Díez (2000). [2] Onion bulb shape out following TG/46/6 UPOV descriptors. [3] Onion types different to those described by Castell and Díez (2000). [4] Shape: C: circular. R: -rhombic. BE: broad elliptic. TE: transverse elliptic. TNE: transverse narrow elliptic. BO: broad obovate.

This classification differs to that carried out according to the bulb skin colour trait. In this case the lines can be grouped into four different classes: lines with brown, pale yellow, brownish yellow and brownish red skins. Most of the lines had symmetrical bulbs with one vegetative axe and white flesh (Table 2).

Commercial production

Commercial production of the best local onion lines was slightly higher than that of the commercial varieties (with no significant differences) in 2001, and significantly higher in 2002 (Table 6). There were also great differences between the yields obtained in the different years, probably due to the different climatic conditions. The lines that had the highest yields were 'Ameixenda' —the most productive line in 2001 and 2002— and 'Baldaio' —outstanding in 2002— which clearly exceeded the productions obtained by the commercial cultivars. The yield range of the local lines was shorter than that of commercial varieties, either in 2001 or 2002, and the mean yields of these lines were higher than those of commercial ones.

Dry matter contents

The percentage of dry matter was, in general, slightly higher in the local lines, with the exception of that obtained in the variety 'Paja Virtudes', which was significantly higher than the rest of the varieties and local lines, either in 2001 or 2002 (Table 6). Among the local lines, the highest values were obtained for 'S. Xulián' and 'Betanzos', which were clearly evident in the two experiments. Either the means or the percentage ranges were similar in the two group of lines, obtaining higher levels in 2002 than in the previous experiment.

Storage quality

The storage quality, defined by Castell and Díez (2000) as the percentages of sprouted bulbs 12, 16, 20 and 24 weeks after harvest, was better in certain local lines than in the commercial varieties: 'Betanzos', 'San Xulián', 'Caldas de Reis' and 'Vilagarcía' (lines 1 and 2) had similar or even lower percentages of sprouted bulbs than 'Paja Virtudes', the commercial variety with the best storage qualities (Table 7). The quality ranged, either in the local or in the commercial cultivars, from

Table 6. Yields (t ha^{-1}) and dry matter content (%) of the local and commercial onion (*Allium cepa* L.) lines studied

Lines		Yields		% dry matter content	
		2001	2002	2001	2002
Local lines					
1.	Ribadeo 1	13.2 ab	30.1 bc	8.46	9.00
2.	Ribadeo 2	16.0 ab	28.5 c	8.23	9.70
3.	Betanzos	14.4 ab	31.6 bc	9.59	12.50
4.	Ameixenda	23.8 a	38.2 ab	7.96	8.00
5.	S. Xulián	15.6 ab	31.2 bc	10.31	11.70
6.	Baldaio	17.9 ab	43.4 a	7.64	9.70
7.	Mondoñedo	13.9 ab	28.3 c	8.77	9.40
8.	Chata-Miño	12.2 ab	32.4 bc	7.89	12.20
9.	Oimbra	15.7 ab	27.0 c	6.51	9.00
10.	Caldas	18.8 ab	24.8 cd	8.84	9.10
12.	Vilagarcía 1	22.3 a	30.4 bc	9.21	9.80
13.	Vilagarcía 2	18.9 ab	31.0 bc	9.56	9.60
14.	Outes	20.5 ab	31.0 bc	8.04	8.40
15.	Arcade	23.2 a	28.8 c	8.06	8.00
16.	Ponteareas	18.9 ab	26.3 cd	8.41	10.00
Commercial varieties					
19.	Paja Virtudes	13.7 ab	17.4 de	11.87	13.0
20.	Babosa	4.5 b	32.5 bc	7.50	8.00
21.	Castillo	18.1 ab	28.0 c	7.12	8.20
22.	Arctic	9.9 b	29.3 c	7.40	9.80

Yield mean, in t ha^{-1}, of three replicates per line and year. Means of the same column followed by the same letter are not significantly different based on a Waller-Duncan multiple range test at P = 0.05.

lines with very low quality to those specified before which had high level quality following the descriptors of Castell and Díez (2000).

Discussion

Considering the grouping criteria used by Castell and Díez (2000) —employed to characterize local onion lines collected all over Spain— based mainly on the bulb type as well as the skin and flesh colours, the situation differs from that described in this work. Most of the Galician local lines are situated in the 4.3.2 subgroup of the red storage type (Table 5), including either transverse elliptic or transverse narrow elliptic bulb lines. Only five lines were situated in different groups: 'S. Xulián' can be considered as a Red Storage type line belonging to the 4.3.4 subgroup and 'Ribadeo', 'Oimbra', 'Outes' and 'Cea' may be included in the 4.4.1. subgroup of the conical type class. It is important to mention that four of the eighteen lines cannot be clearly included in any of the groups defined by Castell and Díez (2000), mainly because of the skin colour. Most of the northwestern local lines have a skin colour ranging from dark brown to pale yellow and should not be all included in the same subgroup. A similar situation takes place with bulb shape: the descriptors used for characterization of the Spanish local lines do not distinguish well between transverse elliptic and transverse narrow elliptic shapes (UPOV, 1999) being all considered oval bulbs. This is specially important if we consider the fact that there were no northwestern entries in the catalogue described by these authors (Castell and Díez, 2000). The redefinition of classes using more precisely defined descriptors —such as the UPOV (1999) descriptors for example— and an increase in the number of entries, including several from the northwest and other parts of Spain, would improve the characterization.

Percentages of dry matter content are negatively correlated with percentages of sprouted bulbs (Fig. 2) —though the R^2 of the regression is relatively low— which is to say that storage quality, measured by the percentages of sprouted bulbs, is positively correlated with percentages of dry matter content. Mattana and Lobo (1980) reported increases in the storage quality of onion lines with higher percentages of dry matter contents as well as of lines with smaller bulbs. This usually takes place with onions that develop bulbs during long-day periods. Patil and Kale (1985) reported that storage losses were positively correlated with protein content and negatively correlated with ash, potassium, and dry matter content, as well as total soluble solids and nonreducing sugars. Storage quality is also reported to be negatively correlated with certain bulb morphological traits such as bulb and neck

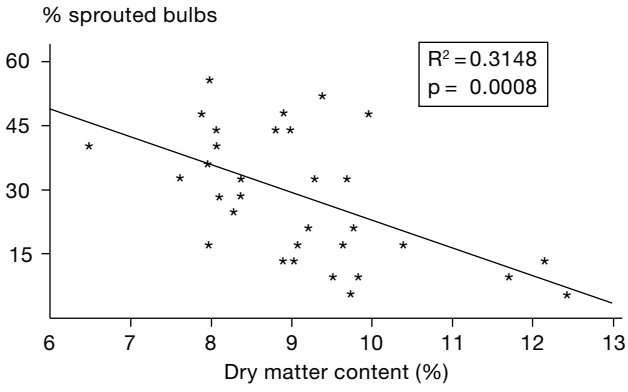

Figure 2. Regression curve for percentage of sprouted bulbs 24 weeks after harvest *vs.* % dry matter content.

Table 7. Storage quality of local and commercial onion (*Allium cepa* L.) lines studied

Lines	Weeks after harvest[1] (2001)				Storage quality[2]	Weeks after harvest[1] (2002)				Storage quality[2]
	12	16	20	24		12	16	20	24	
	% of sprouted bulbs					% of sprouted bulbs				
Local lines										
1. Ribadeo 1	7.3	9.8	20.4	26.5	Medium	0.0	1.2	6.1	12.5	High
2. Ribadeo 2	8.9	13.6	18.8	27.2	Medium	0.0	3.4	6.6	21.1	Medium
3. Betanzos	4.4	7.8	12.0	17.0	High	0.0	0.0	2.1	2.1	High
4. Ameixenda	10.6	15.0	29.4	34.7	Low	1.7	7.6	29.0	52.9	Low
5. S. Xulián	3.9	5.4	9.5	15.4	High	0.0	0.0	1.8	10.0	High
6. Baldaio	11.2	16.7	26.5	32.0	Low	1.8	5.7	16.6	32.0	Medium
7. Mondoñedo	10.1	18.2	30.0	46.1	Low	5.6	11.2	32.5	52.5	Low
8. Chata-Miño	24.1	34.4	42.4	45.0	Very Low	0.0	0.0	3.9	11.6	High
9. Oimbra	33.5	43.6	45.6	40.5	Very Low	18.0	28.2	34.2	42.8	Very Low
10. Caldas de Reis	6.1	6.1	12.4	14.0	High	0.0	2.5	6.8	17.7	High
12. Vilagarcía 1	5.2	9.7	13.1	20.3	High	1.2	1.2	2.5	8.6	High
13. Vilagarcía 2	2.5	2.5	7.3	9.6	High	0.0	1.4	1.4	4.0	High
14. Outes	5.5	17.0	33.4	44.1	Low	0.0	2.7	7.5	27.8	Medium
15. Arcade	6.6	8.3	17.3	39.1	Medium	0.7	1.7	5.6	15.8	High
16. Ponteareas	14.0	20.5	30.6	32.0	Low	3.7	7.0	21.7	48.0	Low
18. Cea	6.4	7.3	16.4	23.8	Medium	—	—	—	—	—
Commercial varieties										
19. Paja Virtudes	3.0	4.5	10.5	16.2	High	1.4	2.7	2.7	7.4	High
20. Babosa	—	—	—	—	—	61.9	75.3	78.7	78.7	Very Low
21. Castillo	15.2	16.1	21.6	25.8	Low	7.5	12.0	19.7	23.9	Medium
22. Arctic	66.2	73.2	73.2	73.9	Very Low	52.1	82.8	86.8	88.3	Very Low

[1] Percentages of sprouted bulbs 12, 16, 20 and 24 weeks after harvest. [2] Storage quality evaluation following Castell and Díez (2000).

diameter (Patil and Kale, 1985b; Rajapakse *et al*., 1992). These correlations could not be confirmed by the data presented in this paper. If further research confirms that storage quality is correlated with certain chemical or morphological traits, the measurements of these characters would be of great use in breeding programs.

From the evaluations carried out in this work it can be concluded that the 18 local lines of northwestern origin can be grouped into three different classes according to morphological traits and into six classes if we also consider the flesh and skin colour. The most productive lines had the worst storage qualities and *vice versa*. Some of these lines had excellent storage qualities as well as good yields and will be employed in breeding programs in the future.

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