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Phenotypic diversity and relationships of fruit quality traits in apricot (*Prunus armeniaca* L.) germplasm

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Abstract Fruit quality attributes were studied for two consecutive years in forty-three apricot cultivars and selections grown in a Mediterranean climate. Physical parameters (weight, size, flesh and skin colour, percentage of blush, firmness and percentage of dry matter), chemical parameters (total soluble solids content and acidity) and sensory parameters (attractiveness, taste, aroma and texture) were evaluated. A high variability was found in the set of the evaluated apricot genotypes and significant differences were found among them in all studied quality attributes. Year-by-year variations were observed for some pomological traits such as harvest date, flesh colour, fruit weight, firmness and soluble solids content. A high correlation was found among some apricot quality attributes. In addition, principal component analysis (PCA) made it possible to establish similar groups of genotypes depending on their quality characteristics as well as to study relationships among pomological traits in the set of apricot genotypes evaluated.

Keywords Fruit quality · Genetic diversity · Germplasm · Principal component analysis · *Prunus armeniaca* L.

Introduction

Apricot (*Prunus armeniaca* L.) is one of the most important and desirable of the temperate tree fruits, with total world production reaching around 2.6 million tonnes (FAO 2005). Fruit quality is fundamental for the acceptance of apricot cultivars by consumers, especially due to the current situation of high competition in the markets with the presence of numerous new cultivars and other fruits and other foods. Fruit quality was defined by Kramer and Twigg (1966) as the conjunction of physical and chemical characteristics which give good appearance and acceptability to the consumable product. Abbot (1999) indicated that quality is a human concept which includes sensory properties (appearance, texture, taste and aroma), nutritional values, chemical compounds, mechanical properties and functional properties. Consumers cherish the beauty and aromatic flavour of high-quality apricots, while other parameters, such as size, resistance to manipulation and good conservation

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aptitude, are especially taken into account by the apricot industry. A lack of sugar or sweetness in purchased apricot fruits is among the most common consumer complaints (Moreau-Rio and Roty 1998). In this sense, new apricot cultivars must be characterised by fruit quality attributes which satisfy the consumers.

Numerous pomological traits influence the fruit quality in apricot (Bailey and Hough 1975; Audergon et al. 1990; Crossa-Raynaud and Audergon 1991; Bassi and Bartolozzi 1993). Souty et al. (1990) proposed the size, colour, firmness, resistance to manipulation, taste, aroma and texture as the fundamental quality attributes in apricot fruit. According to Parolari et al. (1992), sensorial properties in apricot fruits are influenced principally by the sugars and organic acids content, volatile compounds content, colour, size and texture. Firmness, attractiveness and taste are the principal parameters affecting apricot fruit quality in the opinion of Gurrieri et al. (2001).

An important genetic diversity has been observed in the apricot species regarding some quality parameters studied, fundamentally due to the different genetic origins of the cultivated apricot cultivars (Byrne and Littleton 1989; Mehlenbacher et al. 1991; Audergon et al. 1991; Ledbetter et al. 1996; Badenes et al 1998; Hagen et al. 2002; Hormaza 2002; Asma and Ozturk 2005). On the other hand, several reports on peach have shown an important effect of the year on some pomological traits, due to the different climatic conditions (temperature, solar radiation, rainfall, etc.) (Génard and Bruchou 1992; González et al. 1992; Brooks et al. 1993). However, there is scarce information with regard to these year-by-year variations in apricot (Audergon et al. 1991).

The quality parameters may not be independent of each other, and therefore relationships among them should be studied to improve the choice of production objectives for fruit quality and to improve the characterisation of fruit quality by using a limited number of independent parameters. This could be used in breeding programmes and orchard management since the knowledge of the relationships among fruit quality parameters would make it possible to reduce the number of pomological traits for study. In this sense, multivariate analysis is a useful tool which has been used to establish genetic relationship among cultivars and to study correlations among variables (Hilling and Iezzoni 1988; Brown and Walker 1990; Iezzoni and Pritts 1991; Génard and Bruchou 1992; Pérez-González et al. 1993; Esti et al. 1997; Badenes et al. 1998; Gurrieri et al. 2001). Studies carried out in peach (Byrne et al. 1991; Génard and Bruchou 1992; Génard et al. 1994; Esti et al. 1997) have found correlations among some pomological traits. However, we did not find specific reports for apricot concerning the relationships among fruit quality parameters, and only a few studies have included the relationships between certain pomological traits (Pérez-González 1992; Badenes et al. 1998; Gurrieri et al. 2001; Asma and Ozturk 2005).

There is limited information on the global evaluation of fruit quality attributes in apricot and on the relationship among pomological traits linked to the fruit quality. In this work, we investigated physical parameters (weight, size, flesh and skin colour, percentage of blush, firmness and percentage of dry matter), chemical parameters (total soluble solids content and acidity) and sensory parameters (attractiveness, taste, aroma and texture). The aims were to evaluate the fruit quality parameters in the apricot species, in order to investigate the existing phenotypic diversity, and to study the relationships among pomological traits linked to the fruit quality. In addition, multivariate analysis was carried out to study correlations among variables and to establish relationships among genotypes regarding fruit quality attributes. The high number of varieties evaluated, coming from different genetic origins and with a large phenotypic variability, could provide valuable information about the apricot species.

Materials and methods

Plant material

The plant material tested included 34 apricot selections and four new releases ('Rojo Pasión', 'Murciana', 'Selene' and 'Dorada') (Egea et al 2004a, b; 2005a, b) obtained in the apricot breeding programme at the CEBAS-CSIC (Murcia, Spain). In addition, five commercial cultivars ('Currot', 'Mauricio', 'Búlida', 'Orange Red' and 'Bergeron') were included as a reference. All selections and cultivars were cultivated in the same experimental orchard (South–eastern Spain; 37° N latitude, 1° W longitude and 350 m altitude) according to standard apricot orchard management. The pedigree of the apricot genotypes assayed is shown in Table 1.

Table 1 Pedigree and harvest date of apricot genotypes assayed

Genotype	Pedigree	Harvest date	Genotype	Pedigree	Harvest date
Bergeron	Unknown	23-Jun	Z 203/15	Goldrich × P. del Rubio	09-Jun
Búlida	Unknown	31-May	Z 203/8	Goldrich × P. del Rubio	18-Jun
Currot	Unknown	14-May	Z 207/4	Goldrich × P. del Rubio	06-Jun
Dorada	Bergeron × Moniquí	25-Jun	Z 209/1	Goldrich × P.del Rubio	22-Jun
Mauricio	Unknown	26-May	Z 209/17	Goldrich × P. del Rubio	09-Jun
Murciana	Orange Red × Currot	07-Jun	Z 211/18	Goldrich × P. del Rubio	03-Jun
Orange Red	Lasgerdi Mashhad × NAJ2	30-May	Z 212/10	Goldrich × P. del Rubio	19-Jun
Rojo Pasión	Orange Red × Currot	22-May	Z 212/6	Goldrich × P. del Rubio	08-Jun
Selene	Goldrich × A2564	08-Jun	Z 308/6	Goldrich × Lito	08-Jun
S 102/43	Goldrich × Guillermo	02-Jun	Z 308/9	Goldrich × Lito	13-Jun
S 401/33	Goldrich × Currot	21-May	Z 308/12	Goldrich × Lito	12-Jun
S 404/42	Mauricio × Goldrich	24-May	Z 308/14	Goldrich × Lito	16-Jun
S 405/17	Mauricio × Currot	13-May	Z 402/16	Avilara × A2564	05-Jun
S 406/22	A2408 × Currot	22-May	Z 403/2	Avilara × A2564	10-Jun
S 407/8	A2408 × Currot	21-May	Z 501/28	Bergeron × Moniquí	24-Jun
Z 102/19	Bergeron × Moniquí	26-Jun	Z 502/6	Colorao × P. del Rubio	02-Jun
Z 108/38	Gitano × P. del Rubio	06-Jun	Z 503/2	Orange Red × Currot	05-Jun
Z 109/58	Gitano × P. del Rubio	31-May	Z 505/2	Orange Red × Currot	07-Jun
Z 111/61	Gitano × P. del Rubio	19-Jun	Z 506/7	Orange Red × Currot	20-May
Z 115/13	Gitano × P. del Rubio	14-Jun	Z 604/12	Goldrich × Currot	29-May
Z 115/26	Gitano × P. del Rubio	08-Jun	Z 701/1	Orange Red × Currot	02-Jun
Z 201/13	Colorao × Goldrich	01-Jun			

Experimental procedure

All variables were examined in the experimental orchard in two consecutive years (2002–2003). Samples of 50 fruits per genotype were hand-harvested randomly for experimentation at the commercial maturity stage, on the basis of their skin ground colour (fully-coloured). Immediately after harvest, fruits were transported in an air-conditioned car to the laboratory, where they were carefully selected, to ensure that fruits were free of defects, and evaluated at room temperature (23°C). Three replicates of 10 fruits each were selected for each genotype.

Analysis of quality attributes

Skin ground colour (SGC), flesh colour (FC), percentage of blush colour (B), fruit weight (FW), fruit diameter (FD), firmness (F) and percentage of dry matter (DM) were evaluated as physical quality attributes. Skin ground colour and flesh colour were measured with a Minolta chroma meter (CR-300, Minolta, Ramsey, NJ) tristimulus colour analyser calibrated to a white porcelain reference plate. The colour space coordinates L^*, a^*, and b^*, hue angle [$H°^* =$ arctangent (b^*/a^*)] and chroma $[C^* = (a^{*^2} + b^{*^2})^{1/2}]$ were determined around the equatorial region. As suggested by McGuire (1992), hue angle ($H°^*$) and chroma (C^*) have been accepted as more-intuitively-understandable colour variables. In addition, a trained panel of four experts classified the apricots visually into four groups, according to the perception of the skin and flesh colours, as white, yellow, light orange and orange varieties. The percentage of blush colour on the fruit surface was evaluated visually.

Fruit weight was measured by a Blauscal digital balance (model AH-600). A Mitutoyo digital caliper (model CD-15DC, Tokyo, Japan) was used to measure fruit diameter. Firmness was measured on opposite paired cheeks (where the skin was removed) using a Bertuzzi Penetrometer (model FT-327, Facchini, Alfonsine, Italy) equipped with an 8-mm cylindrical plunger. The data are given in kg/0.5 cm^2. Fruit firmness was also evaluated by a compression test using a Lloyd instrument (model LR10K, Fareham Hants, UK) equipped with two (12 × 18 cm) flat plates. The maximum force required to deform the fruit 5 mm, at a speed of 25 mm/min, with the slice lying on the bottom plate, was recorded.

The percentage dry matter was calculated from the loss of weight following oven drying at 105°C. Three fruits without pits were used per genotype. Fresh weight was measured and fruits were cut into smaller pieces, which were placed in a metal tray and then in an oven pre-heated to 105°C. Samples were heated at 60°C for 24 h and subsequently weights were recorded. The difference between the fresh and dry weights makes it possible to calculate the percentage dry matter.

The titratable acidity (TA) and soluble solids content (SSC) were evaluated as biochemical quality attributes. TA was determined by titrating 5 ml of juice with 0.1 mol l^{-1} NaOH to pH 8.1 by an automatic titration system (AOAC 1984); data are given as g malic acid/100 ml, since this is the dominant organic acid in apricot (Souty et al. 1990; Witherspoon and Jackson 1996). The SSC was determined with an Atago N1 hand-held refractometer (Atago Co., Tokyo, Japan); data are given as °Brix.

A trained panel of four experts evaluated the attractiveness (At), taste (Ta), aroma (Ar) and texture (Te) of fruits from each genotype. Scores from 1 to 10 were given for each genotype in the case of attractiveness and taste and from 1 to 5 for aroma. In order to evaluate the texture, fruits were classified in four categories: juicy, fibrous, floury and doughy.

Data analysis

All data are means of 2 years (three replicates of 10 fruits each year), with standard deviations. Statistical analyses were performed using SPSS 12.0 for Windows (Chicago, IL). Differences between genotypes and years as well as genotype-year interactions were determined by analysis of variance (ANOVA). Pearson correlation coefficients were determined. A principal component analysis (PCA) was performed to determinate the relationships among genotypes and among variables using XLStat (Addinsoft, Paris, France) software package.

Results and discussion

Maturity date

All cultivars and selections used were harvested between mid-May and late June (Table 1); there were large variations in harvest season between the tested genotypes. The earliest apricot cultivars and selections were ‘Currot’ and ‘S 405/17’, which were harvested in mid-May. Most cultivars and selections were harvested in late May and early June. New apricot releases ‘Murciana’ and ‘Selene’ as well as reference cultivars ‘Orange Red’ and ‘Búlida’ are included in this group. The latest cultivars and selections were cultivars ‘Bergeron’ and ‘Dorada’ and selections ‘Z 501/28’ and ‘Z 102/19’, which had maturity date in late June.

Significant differences between years were found for the set of evaluated genotypes (Table 4), which could be due to the influence of environmental conditions.

Evaluation of physical attributes

Colour has a significant impact on consumer perception of apricot quality especially regarding fruit attractiveness. The data in Table 2 show values obtained for skin ground colour and flesh colour. The results show a large variability in the set of evaluated apricot cultivars and selections, and significant differences were observed among them (Table 4). Hue value ($H°*$) ranged from maxima of 95.7 and 94.7° for skin and flesh respectively (‘Z 115/26’), which represents a whitish colour, to $H°$ values of around 70° in the case of intense orange genotypes such as ‘S 102/43, ‘Z 207/4’ and ‘Z 212/6’. L* values ranged from 62.0 to 72.5, and similar values were found in skin and flesh for each cultivar and selection. The lowest a* values were around 0.0, both in skin and flesh, while maximum values of 16.4 (‘Z 212/6’) and 19.8 (‘Z 308/12’) were obtained for skin and flesh respectively. Results concerning b* and C* were quite similar and they ranged from minimum values of around 37.0 to

Table 2 Colour values (reflectance measurements L*, a*, b*, H° and C*) at commercial maturity for apricot cultivars and selections[a]

Genotype	Part	Visual colour	L*	a*	b*	H°[b]	C*[c]	% Blush colour
Bergeron	Skin	Light orange	66.9 (1.2)	10.3 (1.9)	51.9 (2.0)	78.8 (0.5)	52.9 (0.7)	9.2 (2.4)
	Flesh	Orange	68.8 (1.6)	12.2 (1.5)	51.2 (1.0)	76.6 (1.2)	52.7 (0.2)	
Búlida	Skin	Light orange	69.4 (3.2)	10.1 (1.2)	47.9 (2.8)	78.0 (2.0)	49.0 (2.5)	8.6 (3.7)
	Flesh	Light orange	67.2 (3.4)	12.0 (1.4)	47.8 (1.3)	75.9 (1.3)	49.3 (1.5)	
Currot	Skin	Yellow (light red)[d]	68.7 (0.8)	0.3 (4.3)	36.9 (2.6)	90.8 (6.6)	37.2 (2.6)	21.8 (7.4)
	Flesh	White	66.2 (1.2)	1.2 (2.4)	34.3 (5.8)	88.5 (3.7)	34.3 (5.9)	
Dorada	Skin	Light orange	69.7 (0.5)	8.1 (1.8)	50.3 (1.9)	80.8 (2.3)	51.0 (1.6)	11.5 (3.5)
	Flesh	Light orange	71.5 (1.4)	6.9 (2.4)	49.4 (0.7)	82.1 (2.6)	49.9 (1.0)	
Mauricio	Skin	Yellow	69.0 (0.4)	1.4 (1.1)	45.0 (1.5)	88.3 (1.4)	45.1 (1.5)	3.0 (1.0)
	Flesh	Yellow	66.8 (1.2)	4.0 (0.8)	41.2 (0.4)	84.5 (1.1)	41.3 (0.4)	
Murciana	Skin	Light orange (red)	69.1 (0.5)	8.6 (0.8)	48.5 (0.8)	80.0 (0.8)	49.3 (0.8)	28.5 (4.5)
	Flesh	Light orange	67.6 (0.9)	12.0 (0.8)	46.3 (1.4)	75.5 (0.7)	47.8 (1.5)	
Orange Red	Skin	Orange (red)	62.4 (1.2)	13.1 (2.6)	49.0 (1.5)	75.0 (0.6)	50.7 (0.5)	30.1 (4.2)
	Flesh	Orange	63.0 (0.9)	14.6 (1.6)	49.9 (1.2)	73.7 (0.4)	52.0 (0.1)	
Rojo Pasión	Skin	Yellow (light red)	67.6 (0.5)	5.7 (1.9)	46.2 (1.6)	83.1 (2.0)	46.5 (1.8)	30.6 (1.4)
	Flesh	Light orange	67.9 (1.3)	9.9 (1.5)	46.3 (1.7)	77.9 (2.1)	47.4 (1.4)	
Selene	Skin	Orange	67.0 (3.6)	14.6 (1.5)	44.5 (2.2)	71.8 (1.0)	46.8 (2.6)	8.7 (3.2)
	Flesh	Orange	66.3 (3.4)	17.8 (0.4)	51.3 (2.3)	70.9 (0.7)	54.3 (2.2)	
S 102/43	Skin	Orange	63.3 (0.5)	15.1 (1.1)	46.4 (1.7)	72.0 (0.9)	48.8 (1.9)	14.8 (5.4)
	Flesh	Orange	65.8 (1.4)	19.1 (0.8)	50.0 (1.5)	69.1 (0.5)	53.5 (1.6)	
S 401/33	Skin	Orange	65.9 (3.6)	8.1 (3.1)	45.6 (1.4)	79.9 (4.0)	46.4 (1.2)	10.1 (3.1)
	Flesh	Orange	68.6 (0.2)	13.4 (1.0)	50.2 (1.5)	75.1 (0.7)	51.9 (1.7)	
S 404/42	Skin	Orange	67.2 (0.4)	10.2 (0.6)	45.5 (1.0)	77.4 (0.7)	46.6 (1.0)	2.3 (1.4)
	Flesh	Orange	66.4 (0.8)	16.3 (0.9)	50.2 (1.1)	72.0 (0.6)	52.8 (1.3)	
S 405/17	Skin	Yellow (light red)	72.0 (2.0)	0.0 (1.2)	45.1 (1.2)	90.1 (1.5)	45.1 (1.2)	18.7 (3.7)
	Flesh	Yellow	70.1 (2.4)	0.4 (1.2)	40.7 (1.1)	89.4 (1.8)	40.7 (1.2)	
S 406/22	Skin	Yellow (light red)	70.1 (0.7)	4.3 (1.0)	46.8 (0.6)	84.7 (1.2)	47.0 (0.6)	28.9 (3.6)
	Flesh	Yellow	69.5 (1.8)	5.8 (1.2)	43.8 (1.4)	82.5 (1.3)	44.2 (1.6)	
S 407/8	Skin	Yellow (light red)	69.7 (2.0)	2.1 (0.9)	47.9 (1.0)	87.5 (1.0)	48.0 (1.0)	16.1 (4.5)
	Flesh	Yellow	67.5 (2.1)	2.0 (0.8)	36.2 (2.4)	86.8 (1.2)	36.3 (2.4)	
Z 102/19	Skin	Yellow	70.9 (1.2)	0.8 (1.5)	47.3 (2.3)	89.0 (1.8)	47.4 (2.3)	10.3 (3.0)
	Flesh	Yellow	70.4 (2.5)	3.3 (1.5)	43.2 (1.4)	85.7 (2.0)	43.4 (1.5)	
Z 108/38	Skin	White	71.5 (0.7)	1.2 (1.2)	37.7 (0.7)	91.9 (1.9)	37.7 (0.7)	11.0 (1.3)
	Flesh	White	70.3 (1.0)	0.3 (0.6)	32.6 (1.6)	90.6 (1.2)	32.6 (1.6)	
Z 109/58	Skin	White (light red)	71.5 (2.9)	0.3 (1.0)	40.3 (2.3)	90.4 (1.4)	40.3 (2.3)	29.2 (6.6)
	Flesh	White	70.1 (1.9)	0.5 (0.7)	38.1 (1.0)	89.3 (1.0)	38.1 (1.1)	
Z 111/61	Skin	Yellow (light red)	68.9 (1.4)	6.6 (3.2)	47.3 (1.3)	82.1 (4.0)	47.9 (0.9)	25.1 (2.6)
	Flesh	Light orange	69.7 (1.5)	5.3 (3.6)	43.5 (1.0)	83.2 (4.6)	43.9 (1.3)	
Z 115/13	Skin	White (light red)	70.8 (0.7)	2.7 (2.6)	44.8 (1.1)	86.6 (3.4)	44.9 (0.9)	21.1 (4.6)
	Flesh	Light orange	68.1 (0.8)	7.8 (4.0)	42.6 (0.7)	79.6 (5.1)	43.4 (1.1)	
Z 115/26	Skin	White (dark rose)	72.2 (1.3)	3.7 (0.9)	36.8 (0.9)	95.7 (1.4)	37.0 (0.9)	30.1 (3.2)
	Flesh	White	71.4 (1.3)	2.2 (0.5)	27.4 (3.8)	94.7 (1.5)	27.5 (3.7)	

Table 2 continued

Genotype	Part	Visual colour	L*	a*	b*	H°[b]	C*[c]	% Blush colour
Z 201/13	Skin	Light orange (red)	67.7 (0.5)	4.8 (1.3)	47.4 (1.0)	84.2 (1.4)	47.7 (1.1)	26.2 (3.7)
	Flesh	Orange	67.0 (1.0)	12.7 (0.6)	49.1 (1.1)	75.5 (0.8)	50.7 (1.0)	
Z 203/15	Skin	Orange (light red)	67.4 (2.5)	13.4 (1.0)	47.9 (1.7)	74.4 (0.8)	49.7 (1.8)	22.5 (2.4)
	Flesh	Orange	69.3 (2.6)	16.8 (1.7)	51.3 (2.7)	71.9 (0.9)	54.0 (3.0)	
Z 203/8	Skin	Light orange	67.3 (2.4)	9.4 (2.4)	47.0 (2.0)	78.6 (3.1)	48.0 (1.7)	5.1 (2.1)
	Flesh	Orange	66.9 (1.1)	11.9 (2.4)	47.3 (0.8)	75.9 (2.5)	48.9 (1.3)	
Z 207/4	Skin	Orange (orange-red)	62.1 (1.6)	14.8 (2.0)	42.7 (1.4)	70.9 (3.0)	45.3 (0.7)	31.8 (5.8)
	Flesh	Orange	63.8 (1.5)	19.7 (0.8)	49.2 (0.9)	68.2 (0.5)	53.0 (1.2)	
Z 209/1	Skin	Yellow	70.2 (1.4)	3.7 (1.0)	49.2 (2.3)	85.6 (1.3)	49.4 (2.3)	9.9 (5.7)
	Flesh	Yellow	71.0 (1.5)	4.3 (1.6)	44.3 (0.6)	84.5 (2.0)	44.5 (0.8)	
Z 209/17	Skin	Orange (orange-red)	62.4 (1.5)	12.9 (2.0)	42.0 (2.3)	72.9 (3.3)	44.0 (1.7)	23.6 (6.7)
	Flesh	Orange	63.7 (1.7)	17.6 (1.4)	48.4 (1.1)	70.0 (1.8)	51.5 (0.7)	
Z 211/18	Skin	Orange	63.7 (0.7)	13.0 (1.1)	43.9 (1.1)	73.5 (1.3)	45.8 (1.2)	16.0 (6.1)
	Flesh	Orange	63.2 (2.1)	15.1 (1.0)	47.8 (0.8)	72.5 (0.9)	50.2 (1.0)	
Z 212/10	Skin	Orange	64.0 (1.1)	15.5 (1.7)	48.0 (1.3)	72.2 (0.3)	50.5 (0.5)	0.0 (0.0)
	Flesh	Orange	67.0 (1.2)	15.8 (1.5)	51.7 (1.8)	73.0 (0.1)	54.1 (0.4)	
Z 212/6	Skin	Orange	64.1 (1.6)	16.4 (0.7)	47.2 (2.1)	70.8 (1.4)	50.0 (1.8)	13.9 (4.2)
	Flesh	Orange	67.6 (3.4)	17.5 (1.6)	52.7 (1.0)	71.7 (1.3)	55.6 (1.4)	
Z 308/6	Skin	Light orange (red)[d]	71.6 (4.4)	6.5 (1.1)	50.2 (1.4)	82.6 (1.4)	50.7 (1.3)	13.4 (2.8)
	Flesh	Orange	71.6 (4.4)	10.9 (1.3)	52.0 (1.1)	78.2 (1.6)	53.2 (0.9)	
Z 308/9	Skin	Light orange (red)	63.2 (1.2)	5.2 (1.3)	46.3 (2.7)	83.6 (1.3)	46.6 (2.8)	32.0 (4.9)
	Flesh	Orange	63.1 (0.6)	9.7 (0.3)	49.2 (1.0)	78.9 (0.3)	50.2 (1.0)	
Z 308/12	Skin	Orange (red)	64.4 (0.5)	16.4 (1.6)	48.5 (0.9)	71.3 (2.0)	51.2 (0.5)	21.7 (3.5)
	Flesh	Orange	64.6 (1.3)	19.8 (1.1)	52.3 (1.0)	69.3 (1.4)	55.9 (0.6)	
Z 308/14	Skin	Orange (red)	67.2 (1.5)	10.3 (2.9)	46.7 (1.6)	77.6 (1.2)	47.9 (0.6)	12.0 (1.0)
	Flesh	Orange	65.4 (1.9)	16.2 (2.5)	49.0 (1.2)	71.7 (0.5)	51.6 (0.2)	
Z 402/16	Skin	Orange (red)	63.9 (0.2)	9.6 (3.3)	43.2 (2.0)	77.7 (3.6)	44.3 (2.6)	30.4 (3.6)
	Flesh	Orange	62.6 (1.5)	16.7 (1.6)	49.2 (1.5)	71.2 (2.2)	51.9 (1.0)	
Z 403/2	Skin	Light orange (red)	67.7 (0.5)	10.6 (0.2)	47.0 (2.0)	77.3 (0.7)	48.2 (1.9)	24.7 (7.4)
	Flesh	Orange	68.7 (2.1)	14.4 (0.8)	45.3 (2.0)	72.3 (1.5)	47.5 (1.8)	
Z 501/28	Skin	Yellow (red)	69.5 (1.3)	1.3 (0.9)	44.4 (2.0)	91.7 (1.1)	44.4 (2.0)	30.1 (5.0)
	Flesh	White	68.9 (1.2)	1.8 (1.0)	40.4 (1.6)	87.5 (1.4)	40.4 (1.7)	
Z 502/6	Skin	Light orange (dark rose)	72.5 (0.8)	3.6 (1.1)	45.9 (0.7)	85.5 (1.3)	46.1 (0.7)	21.3 (4.5)
	Flesh	Light orange	65.9 (1.6)	10.4 (0.5)	45.0 (1.6)	77.0 (1.1)	46.2 (1.4)	
Z 503/2	Skin	Light orange (red)	68.3 (1.0)	12.6 (2.0)	51.6 (1.5)	76.2 (0.3)	53.1 (0.8)	27.7 (3.2)
	Flesh	Light orange	68.7 (2.0)	14.5 (1.1)	48.5 (1.1)	73.3 (0.2)	50.6 (0.5)	
Z 505/2	Skin	Light orange (red)	67.4 (0.4)	10.4 (1.3)	50.7 (1.3)	78.4 (1.3)	51.8 (1.4)	33.1 (4.2)
	Flesh	Orange	69.1 (0.5)	14.2 (0.4)	50.3 (1.5)	74.2 (0.8)	52.3 (1.4)	
Z 506/7	Skin	Light orange (red)	63.1 (1.7)	4.4 (2.4)	42.6 (2.0)	84.0 (3.6)	42.9 (1.7)	19.8 (6.8)
	Flesh	Light orange	61.9 (2.4)	8.7 (1.7)	43.7 (1.9)	78.7 (0.4)	44.6 (0.2)	
Z 604/12	Skin	Yellow	68.7 (1.4)	0.1 (1.3)	44.8 (0.8)	89.9 (1.6)	44.8 (0.8)	5.3 (4.1)
	Flesh	White	67.5 (0.9)	5.8 (1.1)	46.6 (1.9)	82.9 (1.5)	47.0 (1.8)	

Table 2 continued

Genotype	Part	Visual colour	L*	a*	b*	H°[b]	C*[c]	% Blush colour
Z 701/1	Skin	Light orange (red)	66.4 (1.4)	10.6 (2.4)	53.2 (1.4)	78.7 (1.1)	54.3 (0.3)	31.3 (7.5)
	Flesh	Light orange	70.9 (1.2)	11.7 (1.2)	48.9 (1.3)	76.6 (0.7)	50.2 (0.1)	

[a] Standard deviation in parentheses

[b] H° = hue value = arc tg (b*/ a*)

[c] C* = colour intensity (chroma) (a*2 + b*2)1/2

[d] Blush colour of skin given in parentheses

maxima of around 55.0, both in skin and flesh. The visual evaluation showed a high coincidence between the skin ground colour and the flesh colour for each apricot cultivar and selection studied (Table 2). Year-by-year variation was not observed concerning skin ground colour, while significant differences between years were found in the flesh colour (Table 4).

The percentage of blush colour on the fruit surface varied depending on the genotype (Table 2) and significant differences were found according to the statistical analysis (Table 4). A significant group of evaluated accessions, including 'Orange Red', Rojo Pasión', 'Murciana', 'Z 505/2', 'Z 701/1' and 'Z 503/2', showed more than 25% of blush colour on the fruit surface, which influences positively their attractiveness. Significant differences between years were found (Table 4).

The fruit weight ranged from 107.9 g ('Z 308/14') to 37.4 g ('S 405/17') (Table 3) and differences among genotypes were highly significant (Table 4). Previous work on apricot also reported a high variability among cultivars regarding this parameter (Perez-Gonzales 1992; Ledbetter et al. 1996; Badenes et al. 1998). Year-by-year variations were significant according to the statistical analysis (Table 4). As shown also in Table 3, fruit diameter ranged from 41.9 mm ('S 405/17') to 58.3 mm ('Z 308/14').

Values of fruit firmness were higher than 1 kg/0.5 cm^2 for all apricot cultivars and selections, except 'Z 308/14' (Table 3). Most of the genotypes showed values between 1 and 3 kg/0.5 cm^2, suitable for consumers and the apricot industry (Scandella et al. 1998). Values regarding firmness measurement by compression ranged from 24.9 to 62.2 N, although most genotypes showed values between 30 and 50 N. Results obtained by the penetrometer and compression methods were correlated ($r = 0.66$). Significant differences among accessions were observed for both the penetrometer and compression methods (Table 4). A significant year-by-year variation regarding fruit firmness (Table 4) was observed. These yearly variations were more or less marked depending on the apricot genotype. Fruit maturity stage on the harvest date and climatic conditions before harvesting could influence these year-by-year variations in fruit firmness.

There were significant differences among accessions concerning the percentage dry matter (Table 4). Values ranged between 13% and 19% (Table 3), which is in agreement with previous work in apricot (Witherspoon and Jackson 1996; Witherspoon 1999). Cultivar 'Búlida' showed the lowest value (13.0%), while the highest percentage dry matter (19.4%) occurred for selection 'Z 203/8'. A large group of apricot genotypes showed values higher than 17%, a good characteristic for dried apricot. Differences between years were not observed (Table 4). The percentage dry matter is an important quality attribute, especially in the case of apricot cultivars used for production of dried fruit. There is a close relationship between the DM content and quality attributes such as the fruit juiciness and soluble solids content; therefore, valuable information regarding fruit quality is given by this parameter (Witherspoon and Jackson 1996).

Evaluation of chemical and sensory attributes

The soluble solids content ranged from 10.6 °Brix ('Búlida') to 16.2 °Brix ('Z 111/61') (Table 3),

Table 3 Values of physical, chemical and sensorial parameters[a]

Genotype	FW	D	F (kg/0.5 cm^2)	F (N)	DM	SSC	TA	At	Ar	Ta	Te[b]
Bergeron	70.7 (7.0)	51.1 (2.3)	1.70 (0.35)	33.3 (4.7)	14.5 (0.4)	11.9 (0.3)	1.73 (0.07)	7.7	1.5	5.0	J-Fl
Búlida	53.2 (8.9)	47.2 (2.1)	2.15 (0.77)	44.9 (6.3)	13.0 (0.7)	10.6 (0.2)	1.29 (0.05)	7.0	1.6	6.8	J-D
Currot	38.5 (3.8)	41.3 (2.0)	2.95 (1.31)	40.0 (10.7)	13.8 (1.6)	12 (1.2)	1.44 (0.09)	3.0	1.3	5.0	F-D
Dorada	73.1 (8.9)	53.5 (1.9)	1.72 (0.52)	35.7 (5.2)	15.4 (1.0)	13.1 (0.8)	1.25 (0.11)	8.4	2.1	8.3	J-f
Mauricio	49.6 (6.2)	45.0 (2.1)	2.07 (0.86)	39.0 (6.6)	13.3 (1.3)	11.2 (0.4)	1.84 (0.11)	5.6	2.4	6.0	J-F
Murciana	55.5 (5.4)	46.5 (1.9)	2.14 (0.39)	30.9 (4.8)	15.0 (1.1)	12.5 (0.3)	0.92 (0.05)	7.9	1.0	7.0	J
Orange Red	50.9 (6.2)	45.3 (2.6)	3.93 (0.51)	62.2 (16.3)	17.0 (0.2)	14.3 (0.2)	1.24 (0.06)	8.2	1.5	7.0	J-f
Rojo Pasión	46.3 (5.0)	43.3 (1.7)	2.14 (1.59)	36.4 (7.7)	13.8 (0.5)	11.5 (0.3)	1.41 (0.04)	7.7	2.4	6.5	J-Fl
Selene	64.7 (10.8)	49.5 (1.7)	3.15 (0.72)	38.7 (8.7)	17.3 (1.0)	13.4 (0.7)	2.45 (0.10)	7.1	2.0	7.1	J-F
S 102/43	64.8 (13.6)	51.3 (2.0)	1.99 (0.84)	38.2 (13.9)	17.4 (0.9)	14 (0.6)	2.27 (0.17)	6.9	1.5	6.7	J-f
S 401/33	50.3 (6.5)	44.2 (2.1)	1.98 (0.79)	42.0 (9.6)	14.3 (1.5)	12.6 (1.3)	1.83 (0.16)	7.0	1.1	6.7	J
S 404/42	78.6 (10.1)	52.5 (2.5)	1.70 (0.83)	53.5 (10.8)	13.4 (0.8)	11.4 (1.2)	2.16 (0.24)	6.7	2.9	7.2	J-f
S 405/17	37.4 (3.1)	41.9 (1.5)	2.28 (1.57)	48.7 (14.0)	13.8 (0.4)	11.3 (0.5)	1.8 (0.37)	6.8	1.9	5.9	F-D
S 406/22	56.1 (6.0)	46.7 (1.9)	2.00 (0.60)	44.7 (11.1)	16.9 (0.3)	14.6 (0.5)	1.86 (0.23)	7.6	2.2	8.0	J-f
S 407/8	49.6 (6.3)	44.6 (1.6)	1.46 (0.55)	38.7 (12.6)	15.9 (1.1)	13.8 (0.8)	1.39 (0.10)	7.2	3.3	8.0	J
Z 102/19	71.5 (7.5)	52.0 (1.9)	1.26 (0.35)	31.4 (5.4)	18.0 (0.8)	16.1 (1.0)	1.15 (0.08)	8.1	2.8	8.9	J
Z 108/38	67.2 (8.9)	50.7 (2.0)	2.04 (0.63)	28.8 (4.9)	17.9 (1.3)	14.4 (1.4)	1.49 (0.09)	6.1	3.6	8.6	J
Z 109/58	63.3 (8.8)	50.0 (2.3)	3.03 (2.08)	38.8 (7.2)	16.9 (0.8)	15.6 (0.6)	1.57 (0.39)	8.2	4.0	9.2	J
Z 111/61	72.6 (9.0)	52.7 (2.2)	2.55 (0.78)	43.1 (9.0)	18.9 (1.1)	16.3 (0.5)	0.95 (0.15)	8.2	4.1	9.4	J
Z 115/13	94.6 (17.1)	58.0 (2.1)	2.43 (0.81)	42.3 (7.5)	16.8 (1.3)	13.9 (0.5)	1.24 (0.13)	7.2	4.0	9.3	J
Z 115/26	70.4 (13.3)	50.9 (2.5)	2.64 (1.00)	37.9 (4.8)	17.7 (1.6)	15.4 (1.0)	1.13 (0.07)	7.0	3.0	8.8	J
Z 201/13	76.5 (18.7)	51.2 (2.1)	1.90 (0.97)	40.8 (6.8)	15.1 (0.5)	12.8 (0.4)	2.1 (0.18)	7.4	3.2	8.4	J
Z 203/15	64.9 (11.6)	50.7 (2.2)	3.68 (0.64)	44.2 (4.7)	16.3 (0.5)	13.6 (0.6)	2.21 (0.18)	7.7	1.5	5.9	J-f
Z 203/8	63.7 (8.7)	50.5 (2.2)	1.43 (0.40)	24.9 (4.6)	19.4 (0.6)	16 (0.8)	1.87 (0.26)	6.9	2.2	7.4	J-f
Z 207/4	62.8 (9.8)	49.2 (1.6)	1.68 (0.53)	32.9 (8.2)	17.3 (0.4)	13.8 (0.4)	2.1 (0.13)	5.9	4.0	7.4	J
Z 209/1	79.5 (16.5)	54.0 (2.3)	1.06 (0.25)	30.7 (4.4)	17.1 (0.5)	14.6 (0.4)	1.4 (0.07)	6.9	1.7	6.7	F-D
Z 209/17	52.5 (8.5)	47.5 (1.6)	1.37 (0.47)	28.5 (5.5)	18.7 (1.2)	15.1 (0.9)	2.21 (0.25)	5.2	2.2	6.8	J-d
Z 211/18	72.3 (11.6)	51.3 (2.1)	3.28 (0.65)	53.1 (6.8)	15.4 (0.6)	13 (0.3)	2.51 (0.13)	7.2	2.5	6.3	J
Z 212/10	80.4 (8.6)	55.1 (2.5)	2.10 (0.62)	35.1 (9.1)	17.4 (1.1)	15.2 (0.4)	1.69 (0.05)	7.0	1.5	8.0	J-f
Z 212/6	78.3 (16.2)	52.8 (2.4)	3.64 (0.59)	59.1 (13.7)	18.7 (2.9)	13.8 (0.7)	2.6 (0.19)	6.6	1.2	5.2	J-f
Z 308/6	97.7 (13.2)	57.0 (2.8)	1.83 (0.48)	31.2 (7.5)	16.9 (1.1)	13.6 (0.6)	1.82 (0.12)	6.8	1.0	6.5	J
Z 308/9	79.3 (14.9)	52.7 (2.3)	2.53 (0.49)	34.2 (6.5)	13.3 (0.4)	11.4 (0.3)	1.56 (0.10)	7.7	1.5	6.2	J-f
Z 308/12	77.9 (15.9)	53.2 (2.1)	2.24 (0.50)	36.5 (11.8)	13.7 (1.6)	10.6 (0.5)	1.75 (0.04)	7.4	1.2	6.0	J-F
Z 308/14	107.7 (16.5)	58.3 (3.9)	0.99 (0.33)	30.6 (4.8)	13.6 (0.4)	11.7 (0.3)	1.4 (0.08)	6.0	1.5	6.5	Fl
Z 402/16	60.3 (17.0)	47.9 (1.8)	2.51 (0.79)	40.8 (6.7)	16.5 (1.0)	13.9 (0.8)	2.28 (0.03)	8.2	1.2	4.4	J-F
Z 403/2	68.8 (14.2)	50.1 (2.1)	2.09 (0.61)	36.6 (11.5)	16.5 (1.4)	13.8 (0.8)	1.79 (0.30)	8.6	1.5	6.2	J-f
Z 501/28	79.5 (8.9)	53.9 (1.6)	1.46 (0.40)	28.9 (3.6)	17.4 (0.7)	14.9 (0.3)	1.36 (0.09)	7.5	2.2	7.5	J-f
Z 502/6	52.5 (6.0)	47.4 (2.1)	1.94 (1.17)	39.8 (11.5)	17.4 (0.8)	14.6 (0.4)	1.39 (0.14)	7.2	3.6	9.4	J
Z 503/2	44.5 (6.9)	44.0 (2.4)	1.91 (0.74)	40.9 (4.6)	17.7 (0.4)	14.3 (0.2)	1.52 (0.01)	8.5	1.5	7.5	J-F-D
Z 505/2	50.2 (8.0)	46.6 (2.3)	2.67 (0.48)	41.9 (7.9)	14.7 (0.4)	12.9 (0.2)	1.19 (0.08)	7.2	1.0	7.6	J
Z 506/7	43.8 (7.3)	42.3 (1.5)	1.38 (0.82)	27.9 (9.1)	14.1 (0.7)	11.6 (0.3)	1.63 (0.67)	6.2	2.2	7.2	J-F
Z 604/12	65.0 (7.2)	50.9 (1.9)	2.16 (0.85)	51.6 (10.0)	16.2 (0.6)	13 (0.3)	2.38 (0.18)	6.0	1.5	7.3	J-F
Z 701/1	45.9 (5.9)	45.3 (2.2)	2.74 (0.53)	44.7 (9.3)	16.9 (0.3)	14.1 (0.2)	1.38 (0.11)	7.2	3.0	8.0	J-F

[a] Standard deviation in parentheses. *Abbreviations*: FW: fruit weight; D: equatorial diameter; F: firmness; DM: % dry matter SSC: soluble solids content; TA: titratable acidity; At: attractiveness; Ar: aroma; Ta: taste; Te: texture

[b] Texture: J: juicy; F: fibrous; Fl: floury; D: doughy. Capital letter: predominate; Small letter: certain presence

although most of the apricot accessions showed values higher than 12 °Brix. The highest values were determined for selections 'Z 111/61', 'Z 102/19', 'Z 203/8', 'Z 109/58' and 'Z 115/26' (>14 °Brix). The pedigree of these selections included some apricot cultivars belonging to the 'Clases' apricot

Table 4 *F*− values obtained in the ANOVA for the studied factors

Variable	DF	MS	*F*-value	*P*
Harvest date[a]				
Genotype	42	718.33	246.58	0.000
Year	1	1288.04	442.142	0.000
Genotype × year	36	34.49	0.379	0.000
Error	158	2.91		
Skin ground colour				
Genotype	42	252.13	250.40	0.000
Year	1	0.34	0.33	0.564
Genotype × year	36	21.83	21.68	0.000
Error	152	1.01		
Flesh colour				
Genotype	42	271.89	569.82	0.000
Year	1	86.73	181.76	0.000
Genotype × year	35	13.69	28.69	0.000
Error	158	0.48		
% Blush				
Genotype	42	502.58	23.01	0.000
Year	1	112.09	5.13	0.025
Genotype × year	36	178.88	8.19	0.000
Error	160	21.84		
Fruit weight				
Genotype	42	1344.33	89.85	0.000
Year	1	5669.59	378.93	0.000
Genotype × year	36	222.39	14.86	0.000
Error	160	14.96		
Firmness (N)				
Genotype	42	367.43	13.62	0.000
Year	1	615.43	22.81	0.000
Genotype × year	36	144.39	3.73	0.000
Error	159	26.98		
Firmness (kg/0.5 cm^2)				
Genotype	42	2.52	58.60	0.000
Year	1	23.37	543.04	0.000
Genotype × year	36	1.32	30.68	0.000
Error	159	0.04		
Soluble solids content				
Genotype	42	12.95	77.78	0.000
Year	1	1.87	11.24	0.001
Genotype × year	36	1.69	10.16	0.000
Error	158	0.17		
Titratable acidity				
Genotype	42	1.12	102.05	0.000
Year	1	0.04	3.28	0.072
Genotype × year	36	0.09	8.66	0.000
Error	159	0.01		
% Dry matter				
Genotype	42	17.98	24.96	0.000
Year	1	0.30	0.42	0.518
Genotype × year	33	2.99	4.16	0.000
Error	153	0.72		
Attractiveness				
Genotype	42	3.36	5.41	0.000
Year	1	0.89	1.43	0.235
Genotype × year	36	1.32	2.13	0.002
Error	91	0.62		
Taste				
Genotype	42	5.14	7.19	0.000
Year	1	0.24	0.34	0.560
Genotype × year	36	0.83	1.16	0.287
Error	77	0.71		

[a] Harvest date calculated as julian days

group, which is characterised by an excellent gustative quality (Egea et al 1994). A large variability was observed in the set of cultivars and selections examined, and significant differences among them were found (Table 4). An important genetic diversity has been reported previously by other authors (Souty et al. 1990; Egea et al. 1997; Audergon et al. 1991; Gurrieri et al. 2001). The results show a significant year-by-year variation (Table 4), which is in accordance with previous work carried out in apricot (Audergon et al. 1991). The soluble solids content is a very important quality attribute, influencing notably the fruit taste.

The acidity of apricot cultivars and selections is given in Table 3. Values obtained ranged from 0.92 ('Murciana') to 2.60 ('Z 212/6') g malic acid /100 ml, with significant differences among genotypes (Table 4). Our range of values is in agreement with previous work in apricot (Souty et al. 1990; Audergon et al. 1991; Mehlenbacher et al. 1991; Egea et al. 1997; Gurrieri et al. 2001). No year-by-year variation was observed in the case of titratable acidity (Table 4). The fruit maturity stage at the harvest date is the principal factor affecting fruit acidity and also the soluble solids content.

The relationship between TA and SSC has an important role in consumer acceptance of some apricot, peach, nectarine and plum cultivars. Crisosto et al. (2004) reported that in the case of cultivars with TA $> 0.90\%$ and SSC $< 12.0\%$, consumer acceptance was controlled by the interaction between TA and SSC rather than SSC alone. Therefore, a single generic RSSC quality index would not be reliable with regard to assuring consumer satisfaction across all cultivars (Crisosto and Crisosto 2005).

Sensory analysis of attractiveness, aroma, taste and texture is shown in Table 3. The application of sensory analysis using a panel of selected and trained tasters is a reliable and effective method for the evaluation of the organoleptic quality of apricots (Egea et al. 2006) and peach (Bassi and Selli 1990; Colaric et al. 2005). In addition, correlations between analytical measurements and sensory attributes can be evaluated. Most of the apricot cultivars and selections examined showed good characteristics regarding attractiveness and taste (Table 3). In general, low or medium aroma was estimated in the set of evaluated genotypes, although 25% of the apricot cultivars and selections were appreciated as very aromatic fruit. With regard to the fruit texture, most of the genotypes were evaluated as juicy.

Correlations among variables

Significant correlations were found among pomological traits related to the fruit quality (Table 5). The skin ground colour was highly correlated with the flesh colour ($r = 0.93$), which could make it possible to estimate the flesh colour without employing a destructive method. In addition, the visual description of colour was correlated strongly with the hue value ($H°*$), for both the skin ground colour ($r = 0.90$) and the flesh colour ($r = 0.90$). This corroborates the chroma meter as being suitable for colour evaluation. Although significant relationships were observed between the colour measurements and acidity (Table 5), the correlation coefficients were quite low. In general, high hue angle ($H°*$) values could indicate low acidity, while low H* could be related with a higher acidity. However, the coefficient correlations were not sufficiently high to prove this relationship. On the other hand, there was no relationship between colour and firmness or taste (Table 5), in agreement with previous work in peach (Génard et al. 1994).

The tristimulus colour variables have been related to the types and quantities of pigments present in foods. Good correlations have been found between the Hunter a* and $H°*$ (hue) values and the carotenoid concentration in apricot (Ruiz et al. 2005). The colour variables have also been recommended for prediction of both chemical and quality changes in food products (Lozano and Ibarz 1997).

Our results show a very high correlation between fruit weight and fruit diameter ($r = 0.97$); therefore, both parameters can be used to predict each other. This relationship has been reported also by other authors (Biondi et al. 1991; Okut and Akca 1995). Correlation between fruit weight and SSC or TA was not observed, in agreement with previous work in apricot (Badenes et al. 1998; Asma and Ozturk 2005).

Harvest date was correlated significantly with fruit weight ($r = 0.66$) and fruit diameter ($r = 0.75$), which means that early apricot cultivars generally have smaller fruits than late cultivars. Conversely, only a limited relationship was found between harvest date and SSC ($r = 0.42$), and there was no correlation with the acidity (Table 5). Previous work, carried out by Badenes et al. (1998), did not find a correlation between harvest date and fruit weight, while a significant correlation was observed between harvest date and acidity. The differences between our results and those of Badenes et al. (1998) could be explained by differences in the plant material and in the size of the group of cultivars studied.

There was no correlation between firmness and other quality attributes such as colour, fruit weight, SSC and acidity (Table 5), in agreement with previous studies (Ledbetter et al. 1996; Badenes et al. 1998). Recent work in peach reported that ground colour does not seem to be a good indicator of fruit firmness because fruit with the same hue angle had greatly-differing firmnesses (Lewallen and Marini 2003). However, Byrne et al. (1991) found correlations between firmness, TSS, TA and colour attributes among peach cultivars.

The SSC was highly correlated with the DM ($r = 0.93$), while no relationship between SSC and TA was found, as reported previously by Badenes et al. (1998). However, Asma and Ozturk (2005) found a significant correlation between SSC and TA in a group of Turkish apricot cultivars. The differences between our results and those of Asma and Ozturk (2005) could be due to the different ecogeographical groups of apricot cultivars studied.

Table 5 Correlation matrix among the studied variables

	HV	VSGC	VFC	SGC (h°)	FC (h°)	B	FW	D	F (kg/ 0.5 cm^2)	F (N)	SSC	TA	DM	At	Ta
HV	1.000	0.055	0.174	−0.157	−0.104	−0.138	0.658**	0.751**	−0.408**	−0.225	0.419**	−0.185	0.416**	0.368*	0.150
VSGC	0.055	1.000	0.846**	−0.896**	−0.894**	−0.123	0.082	0.062	0.183	0.123	−0.224	0.515**	−0.085	0.028	−0.470**
VFC	–	–	1.000	−0.860**	−0.899**	−0.040	0.231	0.201	0.093	0.100	−0.189	0.372*	−0.065	0.222	−0.363*
SGC (h°)	–	–	–	1.000	0.935**	0.073	−0.094	−0.118	−0.181	−0.195	0.101	−0.461**	−0.079	−0.133	0.378*
FC (h°)	–	–	–	–	1.000	0.013	−0.129	−0.123	−0.136	−0.097	0.195	−0.477**	0.024	−0.121	0.382*
B	–	–	–	–	–	1.000	−0.255	−0.276	0.032	0.295	0.137	−0.274	0.084	0.282	0.089
FW	–	–	–	–	–	–	1.000	0.971**	−0.169	−0.172	0.123	0.068	0.132	0.138	0.095
D	–	–	–	–	–	–	–	1.000	−0.172	−0.147	0.242	0.063	0.255	0.181	0.177
F(kg/ 0.5 cm^2)	–	–	–	–	–	–	–	–	1.000	0.683**	−0.154	0.284	−0.100	0.108	−0.089
F (N)	–	–	–	–	–	–	–	–	–	1.000	0.000	0.195	0.058	0.121	−0.146
SSC	–	–	–	–	–	–	–	–	–	–	1.000	−0.120	0.927**	0.263	0.559**
TA	–	–	–	–	–	–	–	–	–	–	–	1.000	0.080	−0.219	−0.472**
DM	–	–	–	–	–	–	–	–	–	–	–	–	1.000	0.187	0.399**
At	–	–	–	–	–	–	–	–	–	–	–	–	–	1.000	0.221
Ta	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.000

*, ** Correlations significant at $P < 0.05$ and $P < 0.01$, respectively. *Abbreviations*: HV: harvest date; VSGC: visual skin ground colour; VFC: visual flesh colour; SGC: skin ground colour (H°); FC: flesh colour (H°); B: % of blush colour on the skin; FW: fruit weight; D: equatorial diameter; F: firmness; SSC: soluble solids content; TA: titratable acidity; DM: % dry matter; At: attractiveness; Ta: taste

The correlation coefficients between analytical and sensory variables were evaluated. The results show that high acidity reduces the taste appreciation while high SSC increases the consumer appreciation of the taste. However, medium correlation coefficients were obtained with both TA and SSC (Table 5); therefore, these relationships are not very clear. A limited relationship was found between taste and colour, with correlation coefficients (*r*) of around 0.40 (Table 5). Significant relationships between analytical measurements and sensory attributes were found in peach by Esti et al. (1997) and Colaric et al. (2005).

Principal component analysis and grouping of genotypes

Principal component analysis (PCA), one of the multivariate statistical procedures, has been used previously to establish genetic relationships among cultivars and to study correlations among fruit traits within sets of apricot genotypes (Brown and Walker 1990; Badenes et al. 1998; Gurrieri et al. 2001; Azodanlou et al. 2003) and peach genotypes (Wu et al. 2003; Esti et al. 1997). Associations between traits emphasised by this method may correspond to genetic linkage between loci controlling traits or a pleiotropic effect (Iezzoni and Pritts 1991).

The PCA carried out in our work showed more than eighty per cent of the variability observed was explained by the first five components (Table 6). PC1, PC2 and PC3 accounted for 28.3%, 22.1% and 16.1% respectively of the variability. Table 7 shows the correlation between the original variables and the first 3 principal components: PC1 represents mainly titratable acidity, total soluble solids, taste and fruit colour; PC2 explains fruit weight, attractiveness and harvest date; PC3 represents mainly firmness and percentage of blush. Figure 1 represents PC1 and PC2 plotted on a bidimensional plane.

Component scores for the accessions evaluated are shown in Table 7. Negative values for PC1 indicate varieties with higher contents of total soluble solids and better taste as well as lower colour intensity. Varieties such as ‘Z 111/61’, ‘Z 115/13, ‘Z 501/28’, ‘Z 115/26’, ‘Z 108/38’ and ‘Z 109/58’ belong to this group (Fig. 1). The highest positive values for PC1 indicate varieties with high acidity and orange fruits (‘Bergeron’, ‘Selene’, ‘Z 212/6’, Z 308/12’, ‘Z 203/15’, ‘Z 211/18’, ‘Z 402/16’, ‘S 404/42’), as shown in Fig. 1. The highest PC2 values correspond to varieties with later harvest date and larger fruits, such as ‘Dorada’, ‘Z 102/19’, ‘Z 212/10’, ‘Z 308/14’, ‘Z 203/8’ and ‘Z 308/6’ (Fig. 1). The group of varieties with the lowest negative PC2 values stands out especially due to their early harvest date and low fruit weight (‘Currot’, ‘Mauricio’, ‘Rojo Pasión’, ‘Z 506/7’ and ‘S 405/17’). The highest PC3 values indicate the firmest varieties and a higher percentage of blush on the skin. Varieties such as ‘Orange Red’, ‘Murciana’, ‘Z203/15‘, Z 505/2’ and ‘Z 701/1’ belong to this group.

Table 6 Eigenvalues and proportion of total variability among apricot genotypes as explained by the first 10 principal components

PC	Eigenvalues	Percent var.	Cumulative
1	2.831	28.308	28.308
2	2.207	22.069	50.377
3	1.609	16.093	66.471
4	0.947	9.472	75.943
5	0.723	7.230	83.173
6	0.551	5.511	88.684
7	0.484	4.838	93.522
8	0.408	4.077	97.599
9	0.135	1.352	98.951
10	0.105	1.049	100.000

Conclusions

A high variability has been found in the set of apricot genotypes evaluated with regard to the studied pomological traits related to fruit quality, and significant differences among apricot cultivars and selections were observed for all quality attributes. The high number of evaluated genotypes, coming from very different genetic origins and with a large phenotypic variability, could provide valuable information about the apricot species, regarding the parameters which influence apricot quality.

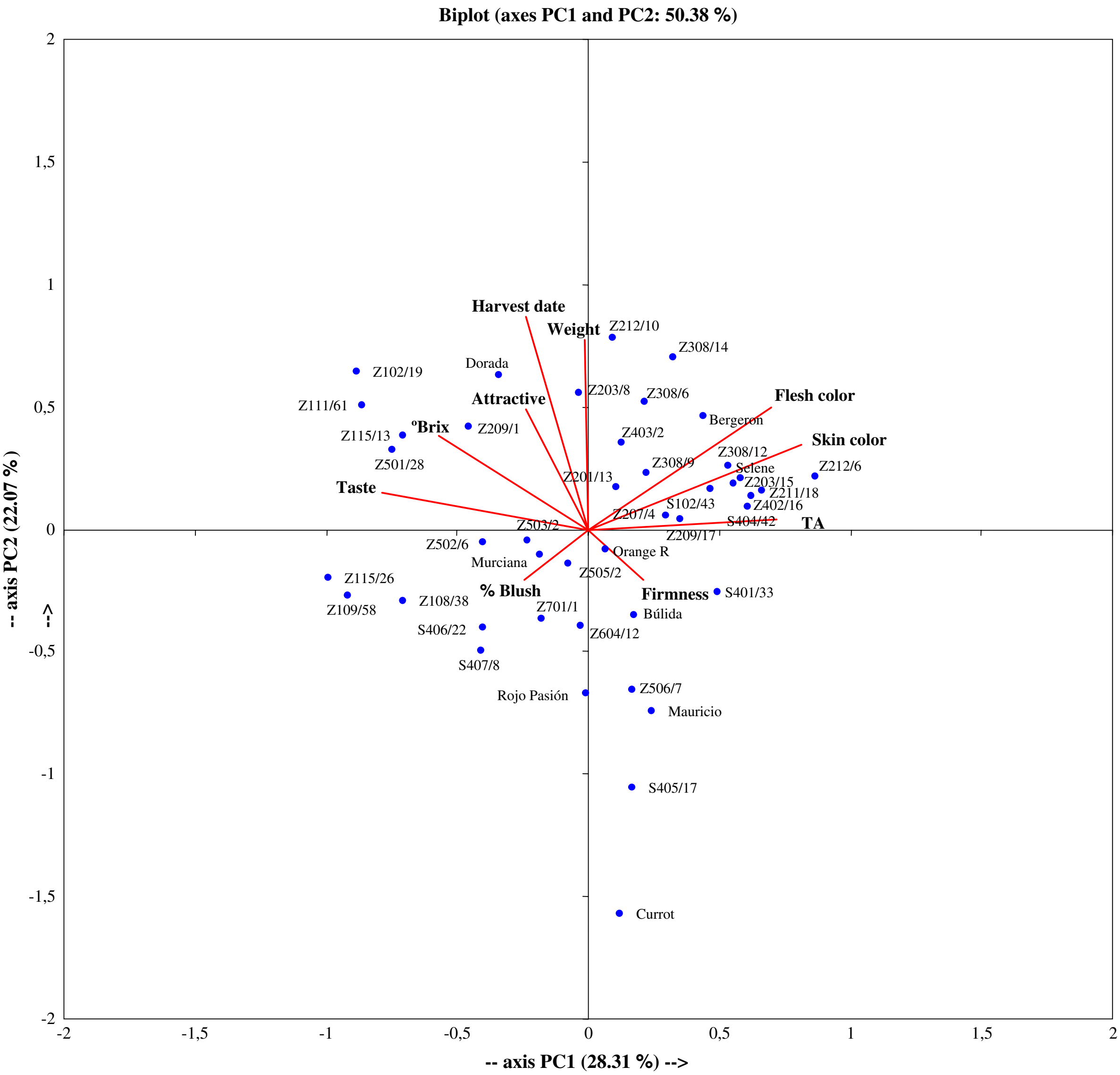

Fig. 1 Segregation of 43 apricot genotypes originating from different genetic origins according to their quality characteristics determined by principal component analysis (PCA)

Significant year-by-year variation has been shown for harvest date, flesh colour, fruit weight, firmness and soluble solids content. However, an effect of the year was not observed for skin ground colour, percentage of blush, titratable acidity, percentage dry matter, attractiveness and taste, which could be due to a greater genetic determination of these pomological traits.

A high correlation was found among some apricot quality attributes, which could reduce the number of pomological traits which need to be studied in breeding programmes and orchard management. In addition, principal component analysis (PCA) made it possible to establish similar groups of genotypes, according to their quality characteristics, as well as to study relationships among pomological traits.

Table 7 Component loadings for quality variables and component scores for 43 apricot varieties

Variable/factor	Component loadings			Genotype	Component scores		
	PC1, $\lambda =$ 28,3%	PC2, $\lambda =$ 22,1%	PC3, $\lambda =$ 16,1%		PC1	PC2	PC3
Tritable acidity (TA)	0.43	0.03	−0.06	Bergeron	1.53	1.41	−0.87
Soluble solids (°Brix)	−0.34	0.26	0.16	Búlida	0.62	−1.09	−0.77
Firmness	0.12	−0.14	0.51	Currot	0.44	−4.84	−1.40
Fruit weight	−0.01	0.52	−0.22	Dorada	−1.18	1.94	−0.39
% Blush	−0.14	−0.14	0.60	Mauricio	0.86	−2.30	−2.14
Attractiveness	−0.14	0.33	0.47	Murciana	−0.64	−0.33	1.07
Taste	−0.47	0.10	0.02	Orange Red	0.25	−0.26	3.29
Skin ground colour	0.49	0.23	0.15	Rojo Pasión	−0.02	−2.06	0.89
Flesh colour	0.42	0.34	0.23	Selene	2.02	0.64	0.29
Harvest date	−0.14	0.58	−0.07	S102/43	1.62	0.50	−0.15
				S401/33	1.73	−0.79	−0.24
				S404/42	2.13	0.28	−1.60
				S405/17	0.59	−3.26	−0.18
				S406/22	−1.404	−1.244	0.68
				S407/8	−1.42	−1.54	−0.64
				Z102/19	−3.074	1.97	−0.94
				Z108/38	−2.45	−0.91	−1.72
				Z109/58	−3.20	−0.84	1.41
				Z111/61	−3.01	1.56	1.29
				Z115/13	−2.45	1.17	−0.26
				Z115/26	−3.46	−0.62	0.47
				Z201/13	0.37	0.54	0.33
				Z203/15	1.95	0.57	1.92
				Z203/8	−0.12	1.70	−1.13
				Z207/4	1.03	0.17	0.25
				Z209/1	−1.59	1.28	−2.02
				Z209/17	1.22	0.11	−0.59
				Z211/18	2.32	0.47	0.81
				Z212/10	0.33	2.41	−1.04
				Z212/6	3.03	0.67	0.54
				Z308/6	0.76	1.59	−1.04
				Z308/9	0.78	0.71	1.11
				Z308/12	1.88	0.80	0.15
				Z308/14	1.14	2.16	−2.31
				Z402/16	2.17	0.42	1.83
				Z403/2	0.46	1.09	1.10
				Z501/28	−2.61	0.99	−0.37
				Z502/6	−1.40	−0.16	0.43
				Z503/2	−0.81	−0.15	1.40
				Z505/2	−0.26	−0.45	1.74
				Z506/7	0.60	−2.02	−0.78
				Z604/12	−0.10	−1.21	−2.09
				Z701/1	−0.62	−1.12	1.69

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