



Evaluation of agronomic and fruit quality traits of fig tree varieties (*Ficus carica* L.) grown in Mediterranean conditions

Cristina Pereira¹, Manuel J. Serradilla², Fernando Pérez-Gragera¹, Alberto Martín³,
María C. Villalobos³ and Margarita López-Corrales¹

¹Junta de Extremadura, Finca La Orden-Valdesequera Research Centre (CICYTEX), Horticulture. Autovía Madrid-Lisboa, s/n, 06187 Badajoz, Spain.

²Junta de Extremadura, Agri-Food Technological Institute of Extremadura (INTAEX-CICYTEX), Plant Food. Avda. Adolfo Suárez, s/n, 06007 Badajoz, Spain. ³Universidad de Extremadura, Escuela de Ingenierías Agrarias, Nutrición y Bromatología. Ctra. de Cáceres s/n, 06071 Badajoz, Spain.

Abstract

In this work, the agronomic behaviour and fruit quality of ten varieties of common fig were evaluated for the establishment of new commercial orchards destined for fresh consumption. The following traits were measured: annual yield, cumulative yield, trunk cross sectional area (TCSA) and yield efficiency of each variety, as well as weight, width, total soluble solids (TSS), pH, titratable acidity (TA) and maturation index (MI) of brebas and figs. The results show that 'Banane' and 'Brown Turkey' were the earliest to enter into production, and 'Banane' showed the highest annual yield in the 7th green (2014), with 76 kg/tree, followed by 'Brown Turkey' (57.6 kg/tree), 'Cuello Dama Blanco' (52 kg/tree) and 'Colar Elche' (39 kg/tree). On the other hand, 'Cuello Dama Blanco' and 'De Rey' exhibited the better organoleptic traits, with TSS and MI values ranged from 18.7 °Brix and 203.3 MI ('Cuello Dama Blanco') to 20.4 °Brix and 187.1 MI ('De Rey') for brebas and from 21.4 °Brix and 278.7 ('Cuello Dama Blanco') to 23.3 °Brix and 255.6 ('De Rey') for figs. This study will allow the fruit grower to select the most interesting and appropriate range of varieties based on market needs taking into account the ripening season (early, middle or late) and fruit colour (green, purple or black).

Additional keywords: yield; brebas; fresh consumption; Spain.

Abbreviations used: CICYTEX (Centro de Investigación Científica y Tecnológica de Extremadura); MI (Maturation Index); TA (Titratable Acidity); TCSA (Trunk Cross-Sectional Area); TSS (Total Solids Soluble).

Authors' contributions: Conceived and designed the experiments: MJS, FPG, AM and MLC. Performed the experiments, statistical analysis: CP and MCV. Critical revision of the manuscript for important intellectual content and supervising the work: MJS, AM and MLC. All authors read and approved the final manuscript.

Citation: Pereira, C.; Serradilla, M. J.; Pérez-Gragera, F.; Martín, A.; Villalobos, M. C.; López-Corrales, M. (2017). Evaluation of agronomic and fruit quality traits of fig tree varieties (*Ficus carica* L.) grown in Mediterranean conditions. Spanish Journal of Agricultural Research, Volume 15, Issue 3, e0903. <https://doi.org/10.5424/sjar/2017153-10403>

Received: 02 Sept 2016. **Accepted:** 24 Jul 2017.

Copyright © 2017 INIA. This is an open access article distributed under the terms of the Creative Commons Attribution (CC-by) Spain 3.0 License.

Funding: INIA (Ministerio de Educación y Ciencia), Spain and ERDF (Project RTA2010-00123C01 & C02); Junta de Extremadura, Research Group AGA001 (Project GR15112); INIA financed a doctoral fellowship to CP (Grnad 30, BOE nº 3, Sec. III. p 12862); the Autonomous Community of Extremadura and the ERDF financed to MLC.

Competing interests: The authors declare that there are no competing interests exist.

Correspondence should be addressed to Margarita López-Corrales: margarita.lopez@juntaex.es

Introduction

In the Mediterranean countries of the European Union, the fig tree (*Ficus carica* L.) is considered as a minor or underutilised species, probably because its cultivated area is small relative to other crops characteristic of this region, such as olives, grapes or oranges. In Spain, this species has been grown and maintained in some of the country's autonomous communities, mainly in small, rain-fed orchards or as scattered trees. Each geographical area has used local plant materials adapted to different uses which are the

result of natural selection promoted by the different soil and climatic conditions, but also artificial selection by farmers.

In Spain, the area under cultivation and the corresponding fig production have slowly fallen from around 20,000 ha and 65,000 tonnes per year in the 1990s to the current values of 12,000 ha and a production of 30,000 tons per year (MAGRAMA, 2015). Among the main reasons for this decline, we can include the limited information about commercial varieties, the few studies available on cultivation techniques (pruning, irrigation and fertilization) (Goldhamer &

Salinas, 1999; Melgarejo, 1996, 1998; Tapia *et al.*, 2003) or harvest and postharvest fruit handling. In recent years, there has been a marked growth in the consumption of both fresh and dry figs, especially in Mexico, the United States, Japan, China and countries of the Persian Gulf (<http://faostat.fao.org/default.aspx>). This has increased the interest of the productive sector in this crop and in the reactivation of fig tree cultivation, especially in areas where such cultivation is traditional. This would mean introducing these fruits into different food industries, the development of new products and an increased supply in different national and international markets. However, the potential development of increased fig production is connected to the introduction of modern agricultural techniques and the selection of productive cultivars with optimized fruit quality-related parameters such as weight, width, shape and colour of the skin and pulp, taste, aroma, soluble solids content and acidity (Flaishman *et al.*, 2008). Also, the development of appropriate postharvest techniques would help to preserve and prolong the life of the fruit, promoting access to new markets (Crisosto *et al.*, 2011; Villalobos *et al.*, 2014). Countries like Turkey, Israel, Egypt, USA and Chile have studied varieties and cultivation techniques to improve productivity and fruit quality in new commercial plantations (Assaf, 2001; Botti *et al.*, 2003; Çalişkan & Polat, 2008; Flaishman *et al.*, 2008; Abo-el-ez *et al.*, 2013). In Spain, studies have concentrated primarily on the identification and characterisation of plant genetic resources of this species (Giraldo *et al.*, 2008; 2010) and the application of various techniques for fruit conservation (Villalobos, 2015), with very few studies related to agronomic behaviour, cultivation techniques or improving productivity (Puebla *et al.*, 2003; Valdés *et al.*, 2009).

Consequently, it would be interesting to study different varieties for the establishment of commercial plantations for fresh fig consumption, and to improve and optimise crop management to produce high quality fruits. Therefore, the main objective of this study is to evaluate the agronomic behaviour and fruit quality of ten interesting fig tree varieties for fresh consumption.

Material and methods

Plant material

The study was carried out in an experimental field of the Scientific and Technological Research Center of Extremadura (CICYTEX) in Guadajira, Spain. The soil texture is sandy loam, pH 6.8 and has an average depth of 1.5 m. The climate is semi-temperate, with

mild winters, an average rainfall of 550 mm, and a dry season that runs from the last week of April to the first week of September.

The plant material was obtained from cuttings of the National Germplasm Bank at the CICYTEX.-'La Orden' Institute (Badajoz, Spain). The varieties studied were selected from those available in that collection based on fruit quality traits for fresh consumption: 'San Antonio', 'Banane', 'Cuello Dama Blanco', 'Cuello Dama Negro', 'Tiberio', 'Tres Voltas L'Any', 'Colar Elche', 'Brown Turkey', 'Blanca Bétera' and 'De Rey' (López-Corrales *et al.*, 2011). All varieties were 'common type' fig trees, therefore producing figs parthenocarpically, except for 'Tiberio' which is a 'San Pedro' type that produces a first crop (breba) parthenocarpically and a second (fig) only after caprification. 'Cuello Dama Blanco' and 'Colar Elche' have a dual use, as their figs can also be used for drying (Stover *et al.*, 2007). All varieties except 'Tres Voltas L'Any' are included in the Official Register of Commercial Fig Varieties (BOE, 2011), although only 'Cuello Dama Blanco', 'Colar Elche' and 'Brown Turkey' are produced commercially.

The brebas of all varieties are oblong or ovoid, except 'San Antonio', which is globose. The figs of 'San Antonio' are oblate, while figs of 'Cuello Dama Blanco' are globose and the remaining varieties are oblong. Fruit skin colour ranges from brown in 'Brown Turkey', 'San Antonio' and 'Tiberio', to black-purple in 'Cuello Dama Negro', 'Colar Elche' and 'De Rey' and yellow-green in 'Cuello Dama Blanco', 'Blanca Bétera', 'Tres Voltas L'Any' and 'Banane'. Pulp colour ranges from amber in 'Cuello Dama Blanco', 'De Rey', 'Blanca Bétera' and 'Tiberio' to red in 'Tres Voltas L'Any', 'Brown Turkey' and 'Banane' and pink in 'Cuello Dama Negro' and 'Colar Elche' (López-Corrales *et al.*, 2011).

The experimental design of this trial, located at an altitude of 217 m above sea level, was 4 randomised blocks for each variety, with three trees per block. After a year in a nursery the plants were established in the field in late February of 2007 with a spacing between trees of 5 m × 4 m and a density of 500 trees/ha. As for tree management techniques, the trees were trained into a vase shape, limiting winter pruning to maintain tree height at about 2 m to facilitate harvesting. The trees were watered with a drip irrigation system: the first two years with a single dropper of 4 L/h per tree and from the third year with two droppers per tree, at a frequency of 3 irrigations a week for 5 h/day. This involved about 2,300 m³/ha per year distributed from mid-May to late September; no falling leaves or other signs attributable to a lack of water were observed during the study period. In relation to fertilisation, 400 kg/ha of 9-18-

27 complex fertiliser were used every winter and 100 kg/ha of potassium nitrate in spring taking into account the recommended needs of the fig tree (Jones *et al.*, 1991) and soil nutrient content. Brebas and figs were harvested at the commercial ripening stage, when the fruits began to show the characteristic colour of the variety and the use of slight finger pressure on these fruits was possible. After harvest, the fruits were analysed in the laboratory. Vegetative and fruit quality traits were evaluated over six consecutive years (2009-2014).

Agronomic parameters

For the study of annual yield, cumulative yield, yield efficiency and ripening period, harvesting of brebas and figs was performed by variety, year and block. The fruits were hand-picked by variety and block three times a week from the beginning to the end of the ripening period for brebas and figs. Annual yield was expressed as kg/tree. In addition, for each harvest, 100 fruits were selected at random to determine the percentage of small fruits and damage by birds, mainly starlings (*Sturnus unicolor*). Small fruits were considered those with lower than average weight, about 15-20 grams, depending on the variety. Cumulative yield was defined as the sum of the annual yield over the years of study and were expressed as kg/tree.

Yield efficiency or productivity was calculated as the ratio between cumulative yield in 2014 and trunk cross-sectional area (TCSA) for this year (Pearce, 1952). For this purpose, the circumference of the trunk of each tree was measured in January of 2014 at a distance of 20 cm above the soil surface, and this parameter was calculated for the block using the following equation: $TCSA = p^2/4\pi$ (<http://www.upov.int/edocs/tgdocs/en/tg265.pdf>) being 'p' the trunk perimeter. The results were expressed as cm². Yield efficiency was expressed as kg/cm².

The ripening calendar for each of the varieties was established based on their average maturity dates during the study period 2009-2014, from the start of fig production to the 7th green when it is considered that full production has been reached in this species.

Quality parameters

Total production was weighed by variety and block; each of the harvest was made three times a week, and 10 fruits were randomly selected, representing 40 fruits per variety. About 12 harvests of brebas and 27 of figs were analysed per year, making a total of about 500 brebas and 1000 figs per year. These fruits were selected for commercial aptitude with no damage and

were determined for the following physicochemical parameters during 2011-2014.

Weight, in grams, was determined using a Mettler AE-166 balance, and fruit width, in mm, using a DL-10 digital micrometer (Mitutoyo, Kawasaki, Japan).

Total soluble solid (TSS) content was measured using a RM40 Mettler Toledo digital refractometer. The results are expressed as °Brix. The fruits were selected by block and five fruits of the initial sample were homogenised with a blender and filtered with nylon gauze to determine the TSS.

Titrateable acidity (TA) and pH were determined using a T50 automatic titrator (Mettler Toledo, Madrid, Spain). From the above homogenised samples, 5 g aliquots were diluted to 50 mL with deionised water from a Milli-Q water purification system (Millipore, Bedford, MA, USA). Analyses were conducted and samples were titrated with 0.1 mol/L NaOH up to pH 7.8 (Serrano *et al.*, 2005) Results are expressed as g citric acid/100 g fresh weight (FW). The pH measurements were obtained with a pH meter added to the automatic titrator. The maturation index (MI) or ratio TSS/TA was calculated as the ratio between TSS (°Brix) and TA, which is positively correlated with consumer acceptability (Crisosto *et al.*, 2010; Valero & Serrano, 2013).

Firmness was measured on 10 fruits, both brebas and figs, from each block per variety using a TA.XT2i Texture Analyser (Stable Micro Systems, Godalming, UK) connected to a computer. Force was applied to produce a 6% deformation by a 70 mm aluminium plate. The slope was determined in the linear zone of the force-deformation curve and the results expressed as N/mm (Pereira *et al.*, 2015).

Statistical analysis

Statistical analysis of the data was carried out using SPSS for Windows, 19.0 (SPSS Inc., Chicago, IL, USA). Agronomic and quality parameters were studied by analysis of variance (ANOVA). This analysis allowed for a comparison of the mean differences between groups that were split into two dependent between-subject factors, namely 'variety' and 'year'. For the comparison of mean values, Tukey's honestly significant difference (HSD) test ($p \leq 0.05$) was used.

Results and discussion

Agronomic parameters

With respect to yield results (Tables 1 and 2), all varieties began fig production in the second year

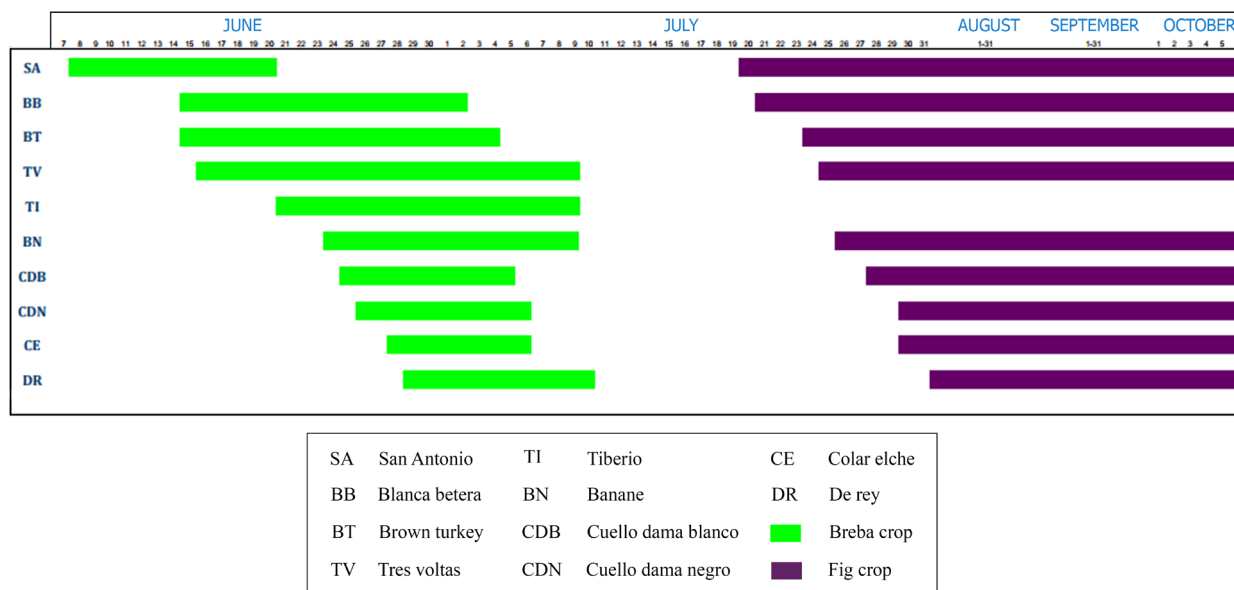


Figure 1. Ripening calendar of the brebas and figs of the 10 fig tree varieties analysed in this work.

(2009). However, in the case of brebas, the start of production was in the third year (2010) because the formative pruning conducted in winter during the first two years of the trial eliminated a large part of the breba harvest. Table 2 shows the differences between varieties. ‘Banane’ and ‘Brown Turkey’ were the earliest to enter into production, with values in the 2nd green (2009) of 12.1 and 6.4 kg/tree respectively, followed by productions that exceeded 25 kg/tree in the 3rd green. ‘Cuello Dama Blanco’, ‘Cuello Dama Negro’, ‘San Antonio’ and ‘Colar Elche’ presented average production values in the 3rd green (2010) that exceeded 10 kg/tree. The remaining varieties, ‘Tres Voltas L’Any’, ‘Blanca Betera’, ‘Tiberio’ and ‘De Rey’, showed a slow entry into production. As for brebas, only ‘Banane’ had a rapid entry into production, with values in the 3rd and 4th greens of 2.21 and 5.14 kg/tree, respectively.

In relation to the ripening dates of the fruits, Figure 1 shows the ripening calendar of the ten varieties of brebas and figs studied. ‘San Antonio’ was the earliest variety for both crops while ‘Cuello Dama Negro’, ‘Colar Elche’ and ‘De Rey’ were the latest. The brebas of ‘San Antonio’ were collected in the second week of June, followed by ‘Blanca Bétera’, ‘Brown Turkey’, ‘Tres Voltas L’Any’ and ‘Tiberio’ which were collected in the third week of June; at the end of June, ‘Banane’, ‘Cuello Dama Blanco’, ‘Cuello Dama Negro’, ‘Colar Elche’ and ‘De Rey’ matured. The figs of ‘San Antonio’ were collected in the second week of July, followed by ‘Blanca Bétera’, ‘Brown Turkey’, ‘Tres Voltas L’Any’ and ‘Cuello Dama Blanco’ in the third week of July and ‘Cuello Dama Negro’, ‘Colar Elche’ and ‘De Rey’ at the end of July.

Regarding the period of collection, shorter periods were recorded for brebas than figs, ranging between 9 and 21 days during June. For figs, the length of the collection period ranged between 67 and 75 days, finishing in the first week of October with the beginning of the first rains and lower temperatures. The ripening calendar of these varieties allows the grower to design commercial planting of this crop according to market needs in terms of date and production demand, as it is possible to provide brebas and figs over the entire campaign.

The results of annual yields, cumulative yield and yield efficiency per block and variety for brebas and figs during the 2009-2014 period are shown in Tables 1 and 2. Annual breba yield (Table 1) was significantly lower than that of figs, showing irregular values between years, while fig yield gradually increased over the years. ‘San Antonio’ and ‘Brown Turkey’ were the varieties with highest breba yield of 15 and 10.6 kg/tree in the 7th green (2014) followed by ‘Banane’, ‘Tres Voltas L’Any’ and ‘Tiberio’ with 5.9, 5.8 and 5.7 kg/tree for the same year, respectively. For figs (Table 2), ‘Banane’ showed the highest annual yield in 2014, with 76 kg/tree, followed by ‘Brown Turkey’ (57.6 kg/tree), ‘Cuello Dama Blanco’ (52 kg/tree) and ‘Colar Elche’ (39 kg/tree).

These differences in yield between brebas and figs were also observed in the cumulative yields (kg/tree) during the same period, with cumulative breba yield being significantly lower than that of figs (Tables 1 and 2). These differences between yields could be explained by the productive traits of each of the varieties. Although ‘Tiberio’ only produced brebas, commercial production was low due to the pruning of trees in this

Table 1. Annual yield, cumulative yield, trunk cross-sectional area (TCSA) and yield efficiency of the brebas produced by 10 different common fig varieties.

Brebas	3rd green (2010) kg/tree	4th green (2011) kg/tree	5th green (2012) kg/tree	6th green (2013) kg/tree	7th green (2014) kg/tree	Cumulative yield (kg/ tree) 2009-2014	TCSA (cm ²)	Yield efficiency (kg/cm ²)
'De Rey'	0.1±0.1 ^{3,f}	0.3±0.2 ^{1,2,3,d}	0.3±0.1 ^{1,2,3,c}	0.3±0.3 ^{2,3,d}	0.7±0.1 ^{1,2,3,e}	1.7	114.2	0.01
'C.D.Blanco'	0.3±0.2 ^{4,5,c,d,e}	1.5±0.4 ^{3,c}	0.6±0.3 ^{4,5,c}	1.8±1.3 ^{2,b}	3.0±1.5 ^{1,c,d}	7.1	143.4	0.05
'B.Turkey'	0.6±0.8 ^{5,c,d,e}	3.2±3.1 ^{2,3,a}	5.5±1.8 ^{2,3,a}	1.7±0.7 ^{4,b}	10.6±2.2 ^{1,b}	18.5	102.8	0.18
'Tiberio'	0.4±0.2 ^{5,c,d,e}	3.5±0.6 ^{3,4,a}	2.9±0.4 ^{3,4,b}	5.7±1.6 ^{1,2,a}	5.7±1.5 ^{1,2,c,d}	18.2	239.6	0.08
'San Antonio'	1.5±1.1 ^{5,b}	3.3±2.0 ^{2,3,4,a}	5.4±1.6 ^{2,3,4,a}	4.8±2.0 ^{2,3,4,a}	15±2.1 ^{1,a}	29.9	107.6	0.28
'C.D.Negro'	0.2±0.2 ^{5,f}	0.6±0.3 ^{3,4,d}	5.0±2.1 ^{1,a}	1.3±0.6 ^{3,4,c}	1.5±1.1 ^{2,e}	8.2	142.8	0.06
'Banane'	2.2±0.7 ^{5,a}	5.1±1.6 ^{2,3,4,a}	3.5±0.9 ^{2,3,4,b}	3.8±0.9 ^{2,3,4,a}	5.9±1.5 ^{1,c}	20.6	134.7	0.15
'Colar Elche'	0.3±0.1 ^{5,c,d,e}	0.5±0.5 ^{5,d}	3.4±0.8 ^{1,2,b}	1.9±1.5 ^{4,b}	2.8±2.0 ^{1,2,c,d}	8.9	133.0	0.07
'Tres Voltas L'Any'	0.2±0.1 ^{5,f}	2.3±0.4 ^{4,b}	2.7±1.1 ^{2,3,b}	3.5±0.5 ^{2,3,a}	5.8±1.2 ^{1,c}	14.6	125.6	0.12
'Blanca Bétera'	0.07±0.05 ^{5,f}	0.7±0.5 ^{3,4,d}	2.5±1.2 ^{1,2,b}	1.0±0.3 ^{3,4,c}	3.8±1.5 ^{1,2,c,d}	8.2	88.2	0.09

In each row, different numbers in superscript indicate a significant difference in annual yield ($p<0.05$). In each column, different letters in superscript indicate a significant difference among varieties ($p<0.05$).

intensive planting and, consequently, this practice is not recommended for future commercial plantings of this variety.

Breba yield per tree obtained in this study was higher than that obtained by Abo-el-ek *et al.* (2013) after 7 years with spacing between trees of 4 × 4 m, where yields observed for 'Kadota' (syn, 'Cuello Dama Blanco') were 0.5 kg/tree. For figs, Khamis *et al.* (2006) after 5 years at a spacing of 3 × 3 m reported tree productions of 17.5 kg/tree for 'Black Mission' and 13.5 kg/tree for 'Kadota', values lower than those obtained in this study. These varieties are synonymous with 'Colar Elche' and 'Cuello Dama Blanco' (López-Corrales *et al.*, 2011), respectively, which were analysed in this study.

With respect to yield efficiency, which is defined as the ratio between cumulative yield and trunk section, during the first years 'San Antonio' and 'Brown Turkey' can be considered as the most productive varieties for brebas, while for figs, these were 'Banane', 'Brown Turkey', 'Cuello Dama Blanco' and 'San Antonio' (Tables 1 and 2).

One of the main problems with this type of commercial orchard during breba and fig harvests is the presence of birds which peck the fruits during ripening, causing major economic losses. In this study, a high percentage of damaged fruits was observed, between 11% and 30% depending on the variety; this value was higher for brebas (30%) than for figs (14%). The

varieties with dark skin and earlier maturing, such as 'San Antonio' and 'Colar Elche', were those with the highest percentage of damaged fruits, 39% and 30%, respectively.

Quality parameters

The results of weight and width, TSS, pH, TA, firmness and maturation index (MI) of brebas and figs of the 10 varieties studied are shown in Table 3. The weight and width of brebas were higher than those of figs. The mean weight ranged from 42.5 g ('De Rey' and 'Tres Voltas L'Any') to 115.8 g ('Brown Turkey') for brebas, while for figs it was between 36.9 g ('Cuello Dama Blanco') and 56.8 g ('Brown Turkey'). The mean width of brebas ranged from 42.4 mm ('De Rey') to 59.2 mm ('Tiberio'), while in figs it ranged from 34.2 mm ('Colar Elche') to 47.3 mm ('San Antonio'). 'Brown Turkey' and 'Banane' were the varieties with the heaviest and widest fruits for both crops, followed by 'Tiberio' in brebas and 'San Antonio' in figs. These values were higher than those obtained by Çalişkan & Polat (2008) and Küden *et al.* (2008) in varieties grown in Turkey, and similar to those obtained by Crisosto *et al.* (2010) in varieties grown in California (USA). Both weight and width are parameters of interest for fruit marketing since the grower receives higher prices for fruits with higher weight and size and, additionally, can select and

Table 2. Annual yield, cumulative yield, trunk cross-sectional area (TCSA) and yield efficiency of the figs produced by 10 different common fig varieties.

Figs	2nd green (2009) kg/ tree	3rd green (2010) kg/ tree	4th green (2011) kg/ tree	5th green (2012) kg/ tree	6th green (2013) kg/tree	7th green (2014) kg/ tree	Cumulative yield (kg/tree) 2009-2014	TCSA (cm ²)	Yield efficiency (kg/cm ²)
'De Rey'	1.2±1.2 ^{6,d}	5.7±2.6 ^{5,e}	11.6±2.6 ^{4,f}	17.1±2.2 ^{3,d}	30.5±8.4 ^{1,f}	26.9±3.7 ^{2,g}	93.1	114.2	0.8
'C.D.Blanco'	4.8±0.6 ^{6,c}	15.4±4.0 ^{5,c}	33.8±9.8 ^{2,b}	31.4±6.5 ^{4,b}	56.7±17.1 ^{1,d}	52±7.9 ^{2,c}	194.1	143.4	1.4
'B.Turkey'	6.4±2.3 ^{6,b}	27.4±11.1 ^{5,b}	33.6±8.2 ^{4,b}	44.8±6.0 ^{3,a}	74.6±17.6 ^{1,a,b}	57.6±11 ^{2,b}	244.5	102.8	2.4
'San Antonio'	1.9±0.5 ^{6,c,d}	12.9±0.9 ^{5,d}	31.8±3.3 ^{3,b,c}	24.9±3.4 ^{4,c}	53.7±12.3 ^{1,d}	34.3±7.9 ^{2,c}	159.5	107.6	1.5
'C.D.Negro'	2.5±2.4 ^{6,c,d}	14.6±7.1 ^{5,c}	27.2±3.2 ^{3,c}	21.6±2.4 ^{4,c}	62.6±8.1 ^{1,b,c}	47.8±6.5 ^{2,c}	176.4	142.8	1.2
'Banane'	12.1±3.5 ^{5,a}	31.2±8.1 ^{4,a}	47.4±5.2 ^{3,a}	55±8.8 ^{2,a}	83.2±21.6 ^{1,a}	76.1±13.1 ^{1,a}	305.1	134.7	2.3
'Colar Elche'	0.9±0.9 ^{5,d}	11.9±3.5 ^{4,d}	23.5±4.5 ^{3,d}	23.2±2.0 ^{3,c}	60.2±5.9 ^{1,b,c}	39±4.1 ^{2,d}	158.7	133.0	1.2
'Tres Voltas L'Any'	0.7±0.6 ^{5,d}	6.9±2.9 ^{5,e}	14.2±2.0 ^{4,e}	19.5±1.1 ^{3,c}	38.3±6.1 ^{1,e}	29.8±8.5 ^{2,f}	109.5	125.6	0.9
'Blanca Bétera'	0.4±0.3 ^{5,d}	5.7±2.1 ^{4,e}	15.7±2.9 ^{3,e}	16.7±3.6 ^{3,d}	27.2±7.5 ^{2,g}	30.2±7.6 ^{1,f}	96.0	88.2	1.1

In each row, different numbers in superscript indicate a significant difference in annual yield ($p < 0.05$). In each column, different letters in superscript indicate a significant difference among varieties ($p < 0.05$).

design the most appropriate packaging for these fruits. Normally, the spanish market demand fig sizes ranging between 30 and 36 mm and commercialised in boxes of about 2.5 to 3 kg with all figs being uniform in size, quality and colour, with absence of external damage.

Based on our the results, 80% of the production of 'San Antonio', 'Banane', 'Cuello Dama Blanco', 'Colar Elche' and 'Blanca Bétera' would be suitable for fresh consumption with brebas and fig widths ranging from 40 to 50.8 for 'San Antonio', 34.2 to 53.1 mm for 'Banane', 40.7 to 47.5 mm for 'Cuello Dama Blanco', 36 to 50.8 mm for 'Colar Elche' and 44.4 to 52.1 mm for 'Blanca Bétera'. When yields of these varieties are low or fruit size is smaller, the production could be used by the industry for the production of syrup, jams, pasta with figs, balsamic vinegars or cakes, pastries, chocolates or sweets. The other varieties such as Tres Voltas, De Rey and Tiberio, due to their low yields, could be mainly used as varieties for the fresh market.

With respect to another of the parameters studied, the opening of the ostiole (data not shown), figs generally had smaller openings than brebas. The exception was 'Brown Turkey', which had larger ostioles in both crops. Varieties with very large ostioles [> 5 mm (IPGRI and CIHEAM, 2003)] are not popular for the fresh fig market as they represent an entry point for microorganisms that can damage the fruit after harvesting (Crisosto *et al.*, 2011).

As shown in Table 3, figs had a higher TSS content than brebas, which were slightly more acidic than figs. The TSS values ranged from 16.4 °Brix ('Brown Turkey') to 20.4 °Brix ('De Rey') for brebas and from 17.5 °Brix ('Banane') to 23.3 °Brix ('De Rey') for figs. 'De Rey' was the variety with the highest TSS values for both crops, followed by 'Cuello Dama Blanco' and 'Tres Voltas L'Any'. In general, these values were lower than those obtained by Çalişkan & Polat (2008, 2012) in different varieties grown in Turkey. However, the TSS values obtained in this study for 'Cuello Dama Blanco', 'Brown Turkey' and 'Cuello Dama Negro' were higher than those obtained by Crisosto *et al.* (2010) for the same varieties grown in California.

As also shown in Table 3, 'Cuello Dama Negro' and 'Blanca Bétera' were the varieties with the highest TA values for brebas, ranging from 0.2 to 0.18% citric acid. For figs the highest TA values were obtained with 'Cuello Dama Negro' and 'Blanca Bétera' with 0.17 and 0.15% citric acid, respectively. 'Cuello Dama Blanco' was the least acidic in figs and 'San Antonio' in breba. These acidity results were lower than those obtained by other authors for different varieties and in different soils and climatic conditions (Crisosto *et al.*, 2010). However, they were similar to those obtained by Çalişkan & Polat (2008) in Turkey. In addition, some fruits of 'Colar Elche' and 'San Antonio' showed cracks in the skin

Table 3. Mean values for weight, size, total soluble solids (TSS) content, pH, titratable acidity (TA), firmness and maturation index (MI) of the brebas and figs produced by 10 different common fig varieties.

Varieties	Weight (g)	Width (mm)	TSS (°Brix)	pH	TA (% citric acid)	Firmness (N/mm)	MI (TSS/TA)
Brebas							
‘De Rey’	42.5 ^{fg}	42.4 ^g	20.4 ^a	6.1 ^a	0.11 ^e	1.3 ^{bc}	203.3 ^a
‘C.D.Blanco’	47.6 ^f	45.7 ^f	18.7 ^b	6.0 ^a	0.11 ^e	1.1 ^f	187.1 ^b
‘Brown Turkey’	115.8 ^a	61.6 ^a	16.4 ^c	5.7 ^b	0.11 ^e	1.3 ^c	149.2 ^c
‘Tiberio’	85 ^e	59.2 ^b	16.5 ^c	5.4 ^c	0.14 ^d	1.1 ^{ef}	123.6 ^d
‘San Antonio’	53.3 ^c	50.8 ^d	16.6 ^c	5.8 ^b	0.10 ^e	1.2 ^{def}	157.5 ^c
‘C.D.Negro’	59.5 ^c	47.1 ^e	18.7 ^b	5.2 ^c	0.20 ^a	1.2 ^{cd}	106.9 ^e
‘Banane’	99.6 ^b	53.1 ^c	15.6 ^f	5.3 ^d	0.16 ^c	1.5 ^a	108.6 ^e
‘Colar Elche’	76.1 ^d	50.8 ^d	18.2 ^c	5.5 ^c	0.13 ^d	1.5 ^{ab}	150 ^c
‘Tres Voltas L’Any’	42.5 ^g	44.8 ^f	18.3 ^{bc}	5.4 ^c	0.17 ^c	0.9 ^g	115.3 ^{de}
‘Blanca Bétera’	57.4 ^c	52.1 ^c	17.6 ^d	5.2 ^c	0.18 ^b	1.2 ^{cde}	105.6 ^e
<i>p</i> variety	***	***	***	***	***	***	***
Figs							
‘De Rey’	39.6 ^{cd}	40.2 ^{cde}	23.3 ^a	6.0 ^a	0.10 ^{ef}	1.1 ^c	255.6 ^b
‘C.D.Blanco’	36.9 ^d	40.7 ^{cd}	21.4 ^b	5.9 ^a	0.08 ^g	1.1 ^c	278.7 ^a
‘Brown Turkey’	56.8 ^a	51.6 ^a	18.4 ^d	5.6 ^c	0.10 ^e	1.3 ^{ab}	198.1 ^d
‘San Antonio’	47.3 ^b	47.3 ^{ab}	20.1 ^c	5.8 ^b	0.09 ^f	1.2 ^{bc}	231.6 ^c
‘C.D.Negro’	44.2 ^{bc}	40 ^{cde}	21.3 ^b	5.2 ^c	0.17 ^a	1.3 ^{ab}	132.5 ^g
‘Banane’	54 ^a	43.9 ^b	17.5 ^e	5.5 ^d	0.11 ^d	1.5 ^a	169.6 ^e
‘Colar Elche’	46.5 ^b	34.2 ^e	20.9 ^b	5.5 ^d	0.13 ^c	1.5 ^a	175.3 ^c
‘Tres Voltas L’Any’	27.2 ^e	36 ^{de}	22.8 ^a	5.6 ^c	0.13 ^c	0.7 ^d	192.4 ^d
‘Blanca Bétera’	38.3 ^{cd}	44.4 ^b	21.0 ^b	5.3 ^c	0.15 ^b	1.2 ^{bc}	151.8 ^f
<i>p</i> variety	***	***	***	***	***	***	***

In each column, different letters in superscript indicate a significant difference among varieties ($p < 0.05$).

produced during the growth and development of the fruit, which was indicative that the fruit had reached full maturity. From a commercial point of view, this cracking can be undesirable because it can be a point of entry for fungi and also result in a loss of moisture that could reduce postharvest life and thus shorten the commercialisation period (Kong *et al.*, 2013). TSS and TA are both related to fruit ripening and influence shelf life and are therefore important parameters for fruit marketing; fruits with higher TSS and lower TA content are the most sensitive to physical damage and, consequently, their shelf life is reduced. In short, figs for marketing should be harvested at commercial maturity or, failing that, in a state of maturity appropriate to their final destination. The results of fruit firmness (Table 3) in brebas and in figs, ranged from 0.7 to 1.5 N/mm for both crops. ‘Colar Elche’ and ‘Banane’ were those that showed the highest firmness with 1.5 N/mm, respectively, for brebas and figs. The brebas and figs

of ‘Tres Voltas L’Any’ presented the lowest values of firmness. These results were consistent with those obtained by Villalobos *et al.* (2014) for ‘San Antonio’ and ‘Banane’, which had values at the beginning of storage of 1.8 and 1.4 N/mm, respectively. The parameters of firmness and skin colour are the two most useful attributes for the selection of fruit in optimum condition for harvesting (Flaishman *et al.*, 2008).

Finally, MI (TSS/TA) (Table 3) is related to fruit flavour and the degree of consumer acceptability. This index was higher in figs than in brebas, showing values between 105 and 203 in brebas and between 132 and 278 in figs. For both crops, ‘De Rey’ and ‘Cuello Dama Blanco’ presented the highest values of 203 and 187 in brebas and 255 and 278 in figs, respectively, followed by ‘San Antonio’ with 157 in brebas and 231 in figs. These values were generally higher than those observed by other authors for other varieties grown in different edaphoclimatic conditions (Çalışkan & Polat, 2008;

Crisosto *et al.*, 2010). Also, figs of 'Cuello Dama de Blanco' showed higher values than those obtained by Crisosto *et al.* (2010), when they were harvested at commercial maturity.

As conclusions, 'San Antonio', 'Cuello Dama Blanco', 'Colar Elche', 'Banane', 'Brown Turkey' and 'Blanca Bétera' showed great potential for fresh consumption because of their high yield and the good quality traits of the fruits. 'San Antonio' was the earliest maturing variety. In all varieties, fig yield was higher than that of brebas, with 'Banane' and 'Brown Turkey' being the most productive for both crops, having the highest yield efficiency and the fruits with the highest values of weight and width. 'Cuello Dama Blanco' and 'De Rey' had high maturation indices (TSS/TA), suggesting a greater acceptance of these fruits by consumers. Finally, this study will allow the fruit grower to select the most interesting and appropriate range of varieties based on market needs taking into account the ripening season (early, middle or late) and fruit colour (green, purple or black).

References

- Abo-el-ez AT, Mostafa RAA, Ibtesam FMB, 2013. Growth and productivity of three fig (*Ficus carica* L.) cultivars grown under Upper Egypt conditions. *Aust J Basic Appl Sci* 7: 709-714.
- Assaf R, 2001. Sélection des varieties locales et techniques de culture du figuier en Israël. *Fruits* 56 (2): 101-121. <https://doi.org/10.1051/fruits:2001118>
- BOE, 2011. Order ARM/2935/2011, that established the inclusion of several varieties of different species in the Register of Commercial Varieties. *Boletín oficial del Estado* nº 262, 31/10/ 2011.
- Botti C, Franck N, Prat L, Ioannidis D, 2003. The effect of climatic conditions on fresh fig fruit field quality and type of crop. *Acta Hort* 605: 37-42. <https://doi.org/10.17660/ActaHortic.2003.605.4>
- Çalışkan O, Polat AA, 2008. Fruit characteristics of fig cultivars and genotypes grown in Turkey. *Sci Hort* 115: 360-367. <https://doi.org/10.1016/j.scienta.2007.10.017>
- Çalışkan O, Polat AA, 2012. Effects of genotype and harvest year on phytochemical and fruit quality properties of Turkish fig genotypes. *Span J Agric Res* 10: 1048-1058. <https://doi.org/10.5424/sjar/2012104-2652>
- Crisosto CH, Bremer V, Ferguson L, Crisosto GM, 2010. Evaluating quality attributes of four fresh fig (*Ficus carica* L.) cultivars harvested at two maturity stages. *HortSci* 45: 707-710.
- Crisosto CH, Ferguson L, Bremer V, Stover E, Colelli G, 2011. Fig (*Ficus carica* L.). In: *Postharvest biology and technology of tropical and subtropical fruits*; Yahia EE (Ed.) Vol 3, pp: 134-158. Elsevier. <https://doi.org/10.1533/9780857092885.134>
- Flaishman MA, Rodov V, Stover E, 2008. The Fig: Botany, horticulture and breeding. *Hortic Rev* 34: 113-197.
- Giraldo E, Hormaza JI, López-Corrales M, 2008. Selection of morphological quantitative variables in the characterization of *Ficus carica* L. *Acta Hort* 798: 103-108. <https://doi.org/10.17660/ActaHortic.2008.798.12>
- Giraldo E, López-Corrales M, Hormaza JI, 2010. Selection of the most discriminating morphological qualitative variables for characterisation of fig germplasm. *J Am Hortic Sci* 135 (3): 240-249.
- Goldhamer D, Salinas M, 1999. Black Mission fig production improved by heavier irrigation. *Calif Agric* 53 (6): 30-34. <https://doi.org/10.3733/ca.v053n06p30>
- Jones JB Jr, Wolf B, Mills HA, 1991. *Plant analysis Handbook II. Micro-Macro Pbs.* Athens, GA, USA. 253 pp.
- Khamis MA, Bakry KA, El-Sayed ME, El-Husseiny AM, 2006. Evaluation of some fig cultivars in Egypt. 2- Fruiting and fruit quality. *J Biol Chem Environ Sci* 1: 105-116.
- Kong M, Lampinen B, Ken S, Crisosto CH, 2013. Fruit skin side cracking and ostiole-end splitting shorten postharvest life in fresh figs (*Ficus carica* L.), but are reduced by deficit irrigation. *Postharvest Biol Tec* 85: 154-161. <https://doi.org/10.1016/j.postharvbio.2013.06.004>
- Küden AB, Bayazit S, Çömlekcioglu S, 2008. Morphological and pomological characteristics of fig genotypes selected from Mediterranean and south east Anatolia regions. *Acta Hort* 798: 95-102. <https://doi.org/10.17660/ActaHortic.2008.798.11>
- López-Corrales M, Gil M, Pérez F, Cortés J, Serradilla MJ, Chome PM, 2011. Variedades de higuera: descripción y registro de variedades. Ministerio de Medio Ambiente y Medio rural y Marino, Madrid. <http://www.magrama.gob.es/>
- MAGRAMA, 2015. Anuario de estadística agroalimentaria 2014. Ministerio de Agricultura, Alimentación y Medio Ambiente, Madrid, Spain. <http://www.magrama.gob.es/>
- Melgarejo P, 1996. La higuera (*Ficus carica* L.). Universidad Politécnica de Valencia, Orihuela, 83 pp.
- Melgarejo P, 1998. El cultivo de la higuera (*Ficus carica* L.). Madrid Vicente A (ed), IRAGRA SA, Madrid.
- Pearce SC, 1952. Studies in the measurement of apple trees. I. The use of trunk girth to estimate tree size. Annual Report of East Mailing Research Station for 1951. pp: 101-104.
- Pereira C, Serradilla MJ, Martín A, Villalobos MC, Pérez-Gragera F, López-Corrales M, 2015. Agronomic behaviour and quality of six cultivars for fresh consumption. *Sci Hort* 185: 121-128. <https://doi.org/10.1016/j.scienta.2015.01.026>
- Puebla M, Toribio F, Montes P, 2003. Determination of fruit bearing pruning date and cutting intensity in "San Pedro" (*Ficus carica* L.) type fig cultivars. *Acta Hort* 605: 147-157. <https://doi.org/10.17660/ActaHortic.2003.605.23>
- Serrano M, Guillén F, Martínez-Romero D, Castillo S, Valero D, 2005. Chemical constituents and antioxidant of sweet cherry at different ripening stages. *J Agric Food Chem* 53: 2741-2745. <https://doi.org/10.1021/jf0479160>

- Stover E, Aradhya M, Crisosto C, Ferguson F, 2007. Overview of the California fig industry and new interest in varieties for fresh fruit. Proc. Calif Plant Soil Conf: Opportunities for California Agriculture, Sacramento, CA, USA. pp: 169-175.
- Tapia R, Botti C, Carrasco O, Prat L, Franck N, 2003. Effect of four irrigation rates on growth of six fig tree varieties. Acta Hort 605: 113-118. <https://doi.org/10.17660/ActaHortic.2003.605.17>
- Valdés G, Escartín N, Lorente M, Malagón J, Bartual J, 2009. Evaluación agronómica y caracterización morfológica de material seleccionado de higuera para producción de brevas en Alicante. Acta Hort 54: 135-138.
- Valero D, Serrano M, 2013. Growth and ripening stage at harvest modulates postharvest quality and bioactive compounds with antioxidant activity. Stewart Postharvest Rev 3 (5): 1-8. <https://doi.org/10.2212/spr.2013.3.7>
- Villalobos MC, 2015. Estudio para la prolongación de la vida útil de variedades de higos y brevas interesantes para consumo en fresco y seco y estudio de técnicas alternativas para el secado de higos. Doctoral thesis. Univ de Extremadura, Badajoz, Spain.
- Villalobos MC, Serradilla MJ, Martín A, Ruiz-Moyano S, Pereira C, Córdoba MG, 2014. Use of equilibrium modified atmosphere packaging for preservation of 'San Antonio' and 'Banane' breba crops (*Ficus carica* L.). Postharvest Biol Tec 98: 14-22. <https://doi.org/10.1016/j.postharvbio.2014.07.001>