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Performance evaluation of 40 fig accessions cultivated in Calabria: Study of qualitative parameters of breba production

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ABSTRACT

In this study, ripening period and several pomological and qualitative characteristics of brebas were determined in forty autochthonous fig accessions grown in Calabria (South Italy). The evaluated forty accessions are characterized by producing brebas with a very different ripening period, carpometric and qualitative characteristics. Regarding the ripening period, on the whole the studied accessions are able to guarantee a very large brebas harvesting period extending for almost seven weeks (from the end of the first ten days of June to the middle of the third ten days of July). Also, most of the accessions produced brebas of carpometric and qualitative characteristics similar or even superior to those produced by other more widespread cultivars. The evaluated accessions can be very important not only for its possible use in genetic improvement programs but also for its immediate use to create new commercial orchards for the production of brebas.

1. Introduction

Among the fruit trees, the fig (*Ficus carica* L.) is undoubtedly-one of the most ancient species (Flaishman et al., 2008). It is hypothesized that its domestication took place in the Jordan Valley about a thousand years before that of cereals (Hirst, 1996; Kislev et al., 2006). Later spread in the Mediterranean Basin through the migrations of peoples, the fig is now practically cultivated all over the world in areas with mild winters and hot and dry summers (Crisosto et al., 2011). Its wide diffusion is essentially due to the remarkable ability of the species to adapt to very different pedoclimatic environments and to the nutritional value of its fruits. Figs are in fact an excellent source of sugars, minerals, vitamins, fibers and polyphenols (Slavin, 2006; Trad et al., 2014; Duman et al., 2018; Solomon et al., 2006); free of sodium, fat and cholesterol (Lianju et al., 2003; Stover et al. 2007). Over 70% of world fig production is produced in the Mediterranean Basin (FAOSTAT, 2020). In this production area, Italy is one of the countries traditionally interested in fig cultivation. Although the species is practically present throughout the Italian territory, almost all of the Italian fig production is obtained in the Southern regions, as the Calabria region, which represents one of the largest and most important Italian fig cultivation areas. Traditionally a large part of the fig industry in this region is based on the cultivation of the "Dottato" variety, whose fruits are usually used to produce dried figs (Mafrica et al., 2017) with a high appreciation by consumers all over the world. However, in recent years the notable increase of local, national and international market demand for fresh figs has opened up new opportunities for fig cultivation in fig-producing countries. The possibility of developing fig cultivation in these regions to obtain fruits for the fresh market represents, in fact, an important business for growers. Among the different types of fresh figs, the greatest business seems to be offered by the production of brebas. This type of fruit is in fact highly appreciated by consumers for the earliness of ripening and the size of the fruit. However, the success of this type of production, in addition to the cultivation techniques, is very dependent on the availability of cultivars that produce high-quality fruits and that are in any case able to meet the needs of the market. The Calabria region has a very rich and diversified fig germplasm in which there are numerous accessions that produce brebas (Mafrica et al., 2021). In consideration of the future important economic perspectives provided by this type of fruit, this manuscript reports the study of production performance of local cultivars/accessions. This work also completes the information relating to 40 accessions previously characterized from a molecular point of view (Costa et al., 2017) thus giving a complete picture of the available wealth of genetic

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resources in order to evaluate their possible use for planting new commercial fig orchards for brebas production.

2. Materials and methods

2.1. Plant materials

The study evaluated the ripening period in the production year of 2019 and the morphological and qualitative characteristics of the produced brebas of forty autochthonous fig accessions identified in a previous survey (Costa et al., 2017). The studied accessions were grown in commercial and experimental orchards, very similar in age and structural characteristics, located between 80 and 200 m above sea level. The orchards were characterized by adult trees, homogeneous, in good vegetative and productive conditions, trained according to the open centre training system, spaced 5.0 × 5.0 m^2, and grown under rain-fed conditions. Starting from 2016 the agronomic management of the plants has been standardized to avoid interference of the cultivation technique on the productive behaviour of the trees. The soil management included a shallow plowing, carried out in late winter to loosen and break up soil and bury the fertilizer scattered on the ground, and periodic cuttings of weeds during spring and summer. The fertilization was carried out at the end of winter with controlled release fertilizer (N:P:K 23:5:10 with microelements) at four kilograms per tree. The pruning, carried out in February, had the aim of limiting the height of the plants to facilitate harvesting operations and uniform the load of the fruiting branches. In particular, the intent of it was on the one hand to safeguard the wood that grew in the previous season (place where the brebas are formed) and on the other to create the conditions to produce a new vegetative growth for a crop of brebas for the next year. In order to guarantee the sanitary integrity of the trees and fruits, continuous monitoring of the main parasites of the fig tree was carried out, using pesticide control treatments when necessary and according to the principles of integrated pest management. Three plants for each accession were used for the study. The used plants chosen randomly and appropriately marked, were similar in terms of the size of the crown and the load of the fruiting branches.

2.2. Fruit harvesting period determination

Eight medium-vigorous fruiting branches on each selected plant were identified in the median portion of the foliage (two for each main cardinal position) to determine the fruit ripening period in May. The evolution of the ripening of the present fruits was monitored on each of these, every-three days starting from the beginning of June and throughout the ripening period, harvesting and recording the ripe ones. The Precocity index (P.I.), which represents the weighted average of the days needed to harvest the entire production starting from 1 January, was then calculated according to the following formula:

$$\textbf{P.I.} = (D1 \times fh1) + (D2 \times fh2) + (D3 \times fh3) + (Dn \times fhn)/TFH.$$

where

D = number of days since 1 January;
fh = number of fruits harvested on each harvest date;
TFH = total number of fruit harvested.

2.3. Fruit sampling

During the middle of the fruit ripening period of each accession, 10 ripe fruits were collected randomly from each plant in different positions around the canopy and at a height of 160 cm (for a total of 30 fruits for each accession). Brebas were harvested at the commercial ripening stage, when the fruits began to show the characteristic color of the variety and the use of slight finger pressure on these fruits was possible. The harvested fruits were immediately placed in refrigerated containers (with an internal temperature around 3 °C) and quickly transported to the laboratory where the main pomological and qualitative characteristics were evaluated.

2.4. Morphological and qualitative evaluation

Three replicates of 10 fruits each were used for the morphological and qualitative evaluations. The fruit weight was determined using an analytical balance (mod. XB 4200C, Precisa, Switzerland), while the fruit width, fruit length, neck length and ostiole width were measured using a digital caliper. (mod.1651DGT, Beta tools s.p.a., Italy). Morphological characterization was done using the IPGRI and CIHEAM (2003) descriptors with further 20 new descriptor characters (Bellini et al., 2007). Later after separating the skin from the pulp, the content of dry matter (DM), total soluble solids (TSS), pH and titratable acidity (TA) were measured on part of the pulp. A homogenate of the fruits pulp of each replica was obtained using a laboratory homogenizer (IKA T 25 digital ULTRATURRAX®, Staufen, Germany). DM content was determined using a Sartorius Moisture Analyzer MA37 thermal balance, by the gravimetric method at 105 °C until constant weight and the results were expressed as a percentage of DM (%). TSS values were measured using a digital refractometer (ATAGO U.S.A., Inc.). The results are expressed as °Brix. TA and pH were determined in 5 g aliquots diluted to 50 mL with deionized water from a water purification system (PURELAB, Elga LabWater, United Kingdom). The analyses were carried out using an automatic titrator (KARL FISCHER 888 TITRANDO, Switzerland). The samples were titrated with 0.1 mol/L NaOH up to pH 7.8. The results are expressed as g of citric acid 100 g^{-1} fresh weight (FW). The ripening index (RI) was then calcu-

Table 1
List of morphological traits used for the Cluster Analysis.

Time of ripening	Scale adhesion	Ease of peeling
Scalarity of ripening	Shape of the fruit stalk	Firmness of the fruit skin
Fresh weight	Fruit ribs	Fruit cavity
Fruit width	Fruit skin cracks	Colour formation in the flesh
Fruit length	Resistance to ostiole-end cracks	Pulp internal colour
Fruit neck length	Bloom	Pulp flavour
Fruit shape	Fruit skin ground colour	Pulp texture
Fruit apex shape	Fruit skin overcolour	Pulp juiciness
Ostiole width	Fruit lenticels quantity	Achenes size
Scale size	Fruit lenticels colour	Total soluble solids
Scale colour	Fruit lenticels size	Titratable acidity

lated as the ratio between TSS (°Brix) and TA (g citric acid 100 g^{-1} fresh weight).

2.5. Statistic analysis

Statistical analysis of the data was carried out using SPSS for Windows, 19.0. (SPSS Inc., Chicago, IL, USA). Biometric and qualitative characteristics were studied by analysis of variance (ANOVA). For the comparison of mean values, Tukey's honestly significant difference (HSD) test ($p \leq 0.05$) was used. Classical cluster analysis was carried out using SYSTAT Software Inc. (Chicago, IL) on 33 morphological and qualitative traits (Table 1).

3. Results

Phenological data evidence substantial and significant differences among accessions related to the ripening period, the duration of the harvesting calendar and the dynamic of the fruits harvested during the ripening period. For the ripening characteristics, the 40 accessions showed a harvesting period of seven weeks (from the end of the first decade of June to the middle of the third decade of July). The fruits of "Bifera bianca CS150", "Bifera nera CS103" and "Columbro bianco CS 198" were particularly early (at the end of the first decade/beginning of the second decade of June). A rather late harvest period affected instead the fruits of "Bifera bianca CS180", "Columbro nero CS27", "Melenzana Stalettì CZ2"and "Niura Moltalto Uffugo CS20", with the central harvesting period falling around the end of the second decade of July. However, in most of the studied accessions, the harvesting period fell between the end of June and the beginning of July, being around 11 days. The harvesting calendar was particularly compact (around 7 days) in "Unifera nera CS122", "Unifera nera CS168", "Bifera nera CS111", "Scava CS199", "Bifera nera CS148"and "Unifera nera CS197", and rather extensive (about 14 days) in "Bifera bianca CS150", "Bifera nera CS110", "Bifera nera CS144"and "Unifera bianca CS166". The analysis of P.I. has moreover evidenced differences among accessions: some of these showed a fairly regular ripening dynamic (with consequent fruit "detachments") during the ripening period. Other accessions, on the other hand, were characterized by a greater incidence of fruits harvested in the first or last part of the harvesting calendar. This resulted that some accessions had lower and higher P.I. with the same ripening periods. Among early cultivars, "Bifera nera CS103" showed a very low P.I. (163,9) with most of fruits ripen in the first part of the harvest calendar, whereas "Bifera bianca CS150" showed a P.I. of 169 and fruit ripening mainly in the second part of the harvest calendar. Conversely, among late accessions, most of the "detachments"

Table 2
Main carpometric characteristics of breba of forty autochthonous fig accessions from Calabria.

Accession	Beginning of fruit maturation	Harvest period (days)		Precocity index	
Bifera bianca CS 157	14 June	11.3	b	168,8	r
Bifera bianca CS139	18 June	13.5	a	172,8	q
Bifera bianca CS150	10 June	13.9	a	169,0	r
Bifera bianca CS158	14 June	11.4	b	168,3	r
Bifera bianca CS173	4 July	13.6	a	194,7	fg
Bifera bianca CS180	12 July	11.5	b	200,6	a
Bifera nera CS103	10 June	11.5	b	163,9	t
Bifera nera CS104	28 June	11.4	b	182,0	o
Bifera nera CS106	8 July	11.5	b	196,6	de
Bifera nera CS108	28 June	11.2	b	185,9	mn
Bifera nera CS109	4 July	11.3	b	192,8	h
Bifera nera CS110	28 June	13.8	a	188,2	kl
Bifera nera CS111	28 June	9.2	c	193,2	gh
Bifera nera CS119	28 June	13.6	a	182,2	o
Bifera nera CS123	4 July	10.8	b	187,5	klm
Bifera nera CS144	18 June	13.7	a	177,1	p
Bifera nera CS147	6 July	11.2	b	190,4	ij
Bifera nera CS148	2 July	9.3	c	185,5	n
Bifera nera CS175	8 July	10.8	b	191,7	hi
Citrulara CS31	10 July	11.5	b	198,6	bc
Columbro bianco CS 198	12 June	11.3	b	165,7	s
Columbro nero CS27	12 July	11.6	b	195,7	ef
Melenzana Pedivign. CS16	10 July	11.5	b	198,7	bc
Melenzana Stalettì CZ2	12 July	11.6	b	200,3	ab
Mpernale CZ1	28 June	11.5	b	181,9	o
Niura Canna CS11	28 June	11.3	b	186,5	lmn
Niura Moltalto Uffugo CS20	12 July	11.4	b	200,6	a
Scava CS199	6 July	9.2	c	193,2	gh
Schiava CS132	28 June	11.3	b	181,4	o
Signorella CS129	10 July	11.3	b	198,2	cd
Unifera bianca CS166	28 June	13.7	a	188,8	jk
Unifera bianca CS179	20 June	11.3	b	173,4	q
Unifera bianca CS195	18 June	11.5	b	172,0	q
Unifera nera CS122	14 June	9.1	c	167,5	rs
Unifera nera CS165	28 June	11.5	b	181,6	o
Unifera nera CS168	2 July	9.1	c	185,3	n
Unifera nera CS190	4 July	10.7	b	192,0	hi
Unifera nera CS191	6 July	11.0	b	195,0	efg
Unifera nera CS193	28 June	10.7	b	185,9	mn
Unifera nera CS197	2 July	9.3	c	185,4	n
Sign.		**		**	

**Significance at p < 0.01.
Different letters in columns represent statistically significant differences among accessions at p < 0.05.

Table 3
Main carpometric characteristics of breba of forty autochthonous fig accessions from Calabria.

Accession	Fruit weight (g)		Fruit length (mm)		Fruit width (mm)		Neck length (mm)		Ostiole width (mm)	
Bifera bianca CS 157	69.8	f-j	66.2	e-j	50.9	e-h	12.4	j-n	1.9	j-l
Bifera bianca CS139	78.3	c-f	67.6	d-i	52.3	b-f	12.7	i-n	2.6	d-l
Bifera bianca CS150	87.0	bc	72.2	d-f	51.8	c-g	9.6	m-p	2.8	c-l
Bifera bianca CS158	70.7	e-i	73.3	d-f	43.3	k-o	18.6	b-g	3.8	b-j
Bifera bianca CS173	66.5	f-l	60.3	i-m	48.2	e-k	11.0	l-p	3.6	b-j
Bifera bianca CS180	46.2	p-r	58.8	j-n	45.8	h-m	8.0	*n*-q	3.3	c-k
Bifera nera CS103	39.6	r	53.8	mn	35.9	q	5.6	pq	2.2	h-l
Bifera nera CS104	84.4	b-d	64.7	f-j	56.7	bc	11.5	l-o	2.9	c-l
Bifera nera CS106	87.9	bc	62.5	g-k	50.0	e-j	17.1	b-k	4.8	a-c
Bifera nera CS108	83.5	b-d	58.3	j-n	53.6	b-e	11.3	l-o	4.0	b-j
Bifera nera CS109	71.2	e-h	69.7	d-g	50.1	e-i	17.5	b-k	3.5	k
Bifera nera CS110	54.6	m-q	73.2	d-f	39.9	*n*-q	19.2	a-f	4.0	b-j
Bifera nera CS111	55.0	l-q	74.0	d-f	41.2	m-q	18.4	b-h	2.1	h-l
Bifera nera CS119	122.6	a	65.1	f-j	65.4	a	11.1	l-o	2.9	c-l
Bifera nera CS123	59.1	i-n	72.7	d-f	45.8	h-m	21.3	ab	3.0	c-j-l
Bifera nera CS144	23.4	s	62.1	g-l	20.8	r	16.4	b-l	1.1	l
Bifera nera CS147	44.9	qr	72.2	d-f	38.4	o-q	20.5	a-e	3.2	c-l
Bifera nera CS148	56.8	k-q	75.5	de	44.3	k-n	24.3	A	2.5	e-l
Bifera nera CS175	58.2	j-o	62.1	g-l	47.3	f-l	2.8	qr	4.3	b-g
Citrulara CS31	76.4	c-f	88.0	abc	47.3	f-l	14.3	f-m	3.9	b-j
Columbro bianco CS 198	68.1	f-k	51.6	*n*	51.3	d-g	0.0	r	2.2	g-l
Columbro nero CS27	128.1	a	61.0	h-m	65.9	a	6.9	o-q	6.8	A
Melenzana Pediv. CS16	73.4	d-g	91.3	ab	42.6	l-o	15.7	d-l	4.2	b-h
Melenzana Stalettì CZ2	59.5	h-n	84.0	bc	38.6	o-q	20.9	a-d	3.1	c-l
Mpernale CZ1	70.1	e-j	72.4	d-f	49.7	e-j	7.9	*n*-q	3.1	c-l
Niura Canna CS11	57.2	k-p	92.4	a	37.2	pq	15.2	e-l	3.2	c-l
Niura Moltalto Uff. CS20	74.1	d-g	87.0	a-c	40.8	m-q	21.7	ab	4.6	b-e
Scava CS199	50.4	*n*-r	81.0	cd	36.7	q	17.7	b-j	2.1	i-l
Schiava CS132	59.5	h-n	72.2	d-f	43.4	k-o	17.9	b-i	3.0	c-l
Signorella CS129	53.1	m-q	60.2	i-m	48.6	e-k	13.7	g-m	5.4	ab
Unifera bianca CS166	87.4	bc	61.9	g-l	57.5	B	11.0	l-p	3.2	c-l
Unifera bianca CS179	62.2	g-n	68.4	d-h	47.7	f-l	11.0	l-p	2.7	d-l
Unifera bianca CS195	63.4	g-m	81.1	cd	42.4	l-p	17.1	b-k	2.0	i-l
Unifera nera CS122	76.6	c-f	68.2	d-i	47.1	f-l	12.9	h-n	4.7	b-d
Unifera nera CS165	81.8	c-e	56.6	k-n	56.5	b-d	11.5	l-o	3.7	b-j
Unifera nera CS168	46.4	o-r	58.3	j-n	43.4	k-o	8.0	*n*-q	2.7	d-l
Unifera nera CS190	53.5	m-q	54.2	l-n	44.9	i-n	12.1	k-o	1.4	kl
Unifera nera CS191	58.6	j-n	61.6	h-m	46.8	g-l	15.8	c-l	2.4	f-l
Unifera nera CS193	95.1	b	68.7	d-h	57.2	b	10.9	l-p	4.4	b-f
Unifera nera CS197	66.5	f-l	72.6	df	44.7	j-n	21.1	a-c	4.0	b-j
Sign.	**		**		**		**		**	

**Significance at $p < 0.01$; Different letters in columns represent statistically significant differences among accessions at $p < 0.05$.

were concentrated in the final part of the harvesting calendar, in particular in "Bifera bianca CS180" and "Niura Moltalto Uffugo CS20", with significantly higher P.I. than that of other accessions with a similar maturation calendar (Table 2). The mean weight of the fruits ranged from 23,4 g ("Bifera nera CS144") and 128,1 g ("Columbro nero CS27"). In other four accessions the weight of the fruits was quite small, with values that did not exceed 50 g and also in "Bifera nera CS119" and "Unifera nera CS193" the weight was high, close to or above 100 g. The mean weight of most of the fruits ranged anyway from 50 to 90 g. The majority of the accessions had fruits with a length between 55 and 75 mm. The fruits of seven accessions was particularly long (exceeding 80 mm), whereas only those of "Columbro bianco CS198" had a length of about 50 mm. Concerning the fruit width, about 50% of accessions showed values of 40–50 mm. Higher results (exceeding 60 mm) were measured in fruits of "Bifera nera CS119"and "Columbro nero CS27", whereas the fruits of "Bifera nera CS144" were about 20 mm wide (Tab. 3). The neck was particularly pronounced (with a length greater than 20 mm) in six accessions, whereas in less developed in "Bifera nera CS175" (about 3 mm) or also absent in "Columbro bianco CS198". The fruits of most of the accessions showed a neck lenght of 10–20 mm. The width of the ostiole in particularly limited to values lesser than 2 mm in "Bifera nera CS144", "Unifera nera CS190"and "Bifera bianca CS157. They exceeded instead 5 mm in fruits of "Signorella CS129"and "Columbro nero CS27". For over the 70% of the accessions, it ranged from 2 to 4 mm (Table 3). Concerning the fruits morphological characteristics, relevant differences were observed: most of the fruits showed an oblong shape (width-to-length ratio lesser than 9). Only six fruits showed a globose shape (width-to-length ratio in the range of 1,1–9). Fruit skin cracks were few or very limited in almost all accessions; only the fruits of "Columbro nero CS27" possessed an intensely cracked skin. Moreover, a resistance to ostiole-end cracks was observed in fruits of the studied accessions, with positive results for ease of peeling, with the only exceptions for fruits of "Niura Canna CS11"and "Unifera bianca CS195", that proved difficult to peel (Table 4). Higher variability among accessions was noted for firmness of the fruit skin, as illustrated in Table 5 (firm in 11, medium in 20 and soft in 9). High variability of skin colour was also observed in the fruits with the dark shades slightly prevailing over the light ones (13 black; 10 light green, 7 brown, 5 yellow-green; 3 yellow and 2 purple). Moreover, a purple skin overcolour was observed in 75% of fruits. An internal cavity was observed in all fruits except those of "Bifera bianca CS158", "Columbro bianco CS198"and "Unifera nera CS193") whose pulp filled completely the receptacle. The fruit internal cavity was variable: very small, small, medium respectively in 14, 16 and 5, whereas it was particularly large in Niura

Table 4
Main morphological characteristics of breba of forty autochthonous fig accessions from Calabria.

Accession	Fruit shape	Fruit skin cracks	Resistance to ostiole-end cracks	Ease of peeling
Bifera bianca CS 157	Oblong	Minute cracks	Resistant	Medium
Bifera bianca CS139	Oblong	Minute cracks	Resistant	Medium
Bifera bianca CS150	Oblong	Minute cracks	Resistant	Medium
Bifera bianca CS158	Oblong	Minute cracks	Resistant	Easy
Bifera bianca CS173	Oblong	Minute cracks	Resistant	Easy
Bifera bianca CS180	Oblong	Minute cracks	Resistant	Medium
Bifera nera CS103	Oblong	Minute cracks	Resistant	Medium
Bifera nera CS104	Oblong	Minute cracks	Resistant	Medium
Bifera nera CS106	Oblong	Minute cracks	Intermediate	Medium
Bifera nera CS108	Globose	Scarce longitudinal cracks	Resistant	Easy
Bifera nera CS109	Oblong	Minute cracks	Resistant	Medium
Bifera nera CS110	Oblong	Minute cracks	Resistant	Medium
Bifera nera CS111	Oblong	Minute cracks	Resistant	Medium
Bifera nera CS119	Globose	Scarce longitudinal cracks	Resistant	Medium
Bifera nera CS123	Oblong	Minute cracks	Resistant	Medium
Bifera nera CS144	Oblong	Minute cracks	Resistant	Medium
Bifera nera CS147	Oblong	Minute cracks	Resistant	Medium
Bifera nera CS148	Oblong	Scarce longitudinal cracks	Resistant	Medium
Bifera nera CS175	Oblong	Minute cracks	Resistant	Medium
Citrulara CS31	Oblong	Scarce longitudinal cracks	Intermediate	Easy
Columbro bianco CS 198	Globose	Minute cracks	Resistant	Easy
Columbro nero CS27	Globose	Cracked skin	Intermediate	Medium
Melenzana Pediv. CS16	Oblong	Minute cracks	Resistant	Medium
Melenzana Stalettì CZ2	Oblong	Minute cracks	Resistant	Medium
Mpernale CZ1	Oblong	Scarce longitudinal cracks	Resistant	Medium
Niura Canna CS11	Oblong	Scarce longitudinal cracks	Resistant	Difficult
Niura Moltalto Uff. CS20	Oblong	Scarce longitudinal cracks	Resistant	Medium
Scava CS199	Oblong	Scarce longitudinal cracks	Resistant	Medium
Schiava CS132	Oblong	Minute cracks	Resistant	Easy
Signorella CS129	Oblong	Minute cracks	Resistant	Medium
Unifera bianca CS166	Globose	Minute cracks	Resistant	Medium
Unifera bianca CS179	Oblong	Minute cracks	Resistant	Medium
Unifera bianca CS195	Oblong	Minute cracks	Resistant	Difficult
Unifera nera CS122	Oblong	Minute cracks	Intermediate	Medium
Unifera nera CS165	Globose	Minute cracks	Resistant	Medium
Unifera nera CS168	Oblong	Scarce longitudinal cracks	Resistant	Medium
Unifera nera CS190	Oblong	Minute cracks	Resistant	Medium
Unifera nera CS191	Oblong	Scarce longitudinal cracks	Resistant	Medium
Unifera nera CS193	Oblong	Minute cracks	Resistant	Easy
Unifera nera CS197	Oblong	Minute cracks	Resistant	Easy

Canna CS11"and "Unifera nera CS168"). Concerning the fruit pulp colour, light shades prevailed over dark ones and in particular white pulp was present in 10 accessions, amber in 6 ones, pink in 16 ones and red in 7 ones (Table 5).

The dry matter % of pulp was 15–18% in most of the fruits varying with very low values (lesser than 12%) in "Bifera bianca CS157", "Bifera bianca CS158" and "Bifera bianca CS180" and, instead, very high values (above 20%) in fruits of Bifera nera CS123", "Bifera nera CS144", "Bifera bianca CS173", "Bifera nera CS106" and "Unifera nera CS122". Total soluble solids analysis on pulp showed a range of 10,1–23,5 °Brix, with most of fruits possessing a good sugar content (°Brix $\geq$ 16). Fruits of "Bifera bianca CS180" and "Bifera bianca CS158" denoted low values (less than 13°Brix), whereas those of "Bifera nera CS106", "Bifera bianca CS173" e "Unifera nera CS122" were very sugary, showing meanly 20 °Brix. pH values ranged from 5.21 ("Signorella CS129") to 5.54 ("Bifera bianca CS158"). In over 65% of accessions it exceeded 6. A wide range of variability was observed for titrable acidity of pulp (0.15–0.64 g citric acid kg^{-1}) with 7 accessions showing results less than 0.20 g citric acid kg^{-1}, 26 ones between 0.20 and 0.30 g citric acid kg^{-1} e 7 more than 0.30 g citric acid kg^{-1}. Among these last ones, particularly high acid content was detected in "Bifera nera CS144", "Unifera bianca CS195", "Unifera bianca CS179" (more than 0,50 g citric acid kg^{-1}) and "Bifera nera CS103" (more than 0,60 g citric acid kg^{-1}). The Maturation index in fruits varied from 25,4 ("Unifera bianca CS179") and 122,4 ("Bifera nera CS123"): in 7 accessions it was less than 50, in 27 accessions between 50 and 100 and in 6 accessions more than 100 (Table 6).

Cluster analysis denoted large variations among accessions for ripening period and morphological and qualitative parameters of brebas. Moreover, the cluster analysis allowed to divide into defined groups in a dendrogram the accessions with similar characteristics (Fig. 1). Two groups were separated: group I included 26 accessions characterized by almost diversified brebas; group II was much more homogeneous and constituted by 14 accessions with black skin, a high-sugar pulp. Group I was divided into two subgroups (I.A and I.B), the first (I.A) constituted by only 2 accessions ("Columbro bianco CS198"and "Bifera bianca CS 158"), shared by the ripening period, the light green color of the skin and numerous other external and internal fruit characteristics. The second subgroup (I.B) included the remained 24 accessions and it was further divided into two subgroups (I.B.1 e I.B.2), essentially differentiated by some peculiarities of the peel and other internal characteristics. The first included accessions which were characterized by producing brebas with dark skin overcolor, pink lenticels and which mainly had a soft or medium skin firmness, a pink or red and quite juicy pulp. Vice versa, the subgroup I.B.2 grouped accessions with a light skin overcolor and white or green lenticels and with a not very juicy pulp of a generally light color.

The accessions included in Group II were divided in other two subgroups (II.A e II.B) for some skin and pulp characteristics. The subgroup II.A represented accessions characterized to produce bre-

Table 5
Main characteristics of the skin and pulp of breba of forty autochthonous fig accessions from Calabria.

Accession	Firmness of the fruit skin	Fruit skin colour	Fruit skin overcolour	Fruit internal cavity	Fruit pulp colour
Bifera bianca CS 157	Medium	Light green	Absent	Small	White
Bifera bianca CS139	Medium	Yellow green	Absent	Very small	White
Bifera bianca CS150	Firm	Light green	Absent	Very small	White
Bifera bianca CS158	Medium	Light green	Absent	None	White
Bifera bianca CS173	Medium	Yellow	Absent	Small	White
Bifera bianca CS180	Firm	Yellow	Absent	Medium	Pink
Bifera nera CS103	Medium	Black	Purple	Very small	Pink
Bifera nera CS104	Soft	Brown	Purple	Medium	Pink
Bifera nera CS106	Medium	Light green	Purple	Very small	White
Bifera nera CS108	Firm	Brown	Purple	Small	Amber
Bifera nera CS109	Medium	Yellow green	Purple	Small	Pink
Bifera nera CS110	Soft	Black	Purple	Very small	Red
Bifera nera CS111	Soft	Black	Purple	Very small	Pink
Bifera nera CS119	Medium	Yellow green	Purple	Small	Pink
Bifera nera CS123	Medium	Black	Purple	Very small	White
Bifera nera CS144	Medium	Brown	Purple	Medium	White
Bifera nera CS147	Medium	Black	Purple	Small	Pink
Bifera nera CS148	Soft	Black	Purple	Small	Pink
Bifera nera CS175	Medium	Black	Purple	Very small	Pink
Citrulara CS31	Medium	Black	Purple	Medium	Red
Columbro bianco CS 198	Soft	Light green	Absent	None	Amber
Columbro nero CS27	Soft	Brown	Purple	Medium	Red
Melenzana Pediv. CS16	Medium	Black	Purple	Small	Red
Melenzana Stalettì CZ2	Firm	Black	Purple	Small	Pink
Mpernale CZ1	Medium	Purple	Purple	Small	Amber
Niura Canna CS11	Soft	Purple	Purple	Large	Pink
Niura Moltalto Uff. CS20	Medium	Black	Purple	Very small	Pink
Scava CS199	Medium	Black	Purple	Very small	Red
Schiava CS132	Medium	Black	Purple	Small	Red
Signorella CS129	Firm	Yellow	Absent	Very small	Red
Unifera bianca CS166	Firm	Yellow green	Absent	Small	Amber
Unifera bianca CS179	Firm	Yellow green	Absent	Small	White
Unifera bianca CS195	Firm	Light green	Purple	Small	Amber
Unifera nera CS122	Medium	Light green	Purple	Small	Pink
Unifera nera CS165	Firm	Light green	Purple	Very small	Pink
Unifera nera CS168	Soft	Brown	Purple	Large	White
Unifera nera CS190	Medium	Brown	Purple	Very small	Pink
Unifera nera CS191	Soft	Brown	Purple	Small	Pink
Unifera nera CS193	Firm	Light green	Purple	None	Amber
Unifera nera CS197	Firm	Light green	Purple	Very small	Amber

bas which generally had small cracks on the skin, a pulp with pink or red color and quite aromatic. Vice versa, in accessions of subgroup II.B brebas showed a less cracked skin and a less flavorful pulp. The subgroup II.A was divided in other two groups (II.A.1 e II.A.2), discriminating the accessions based on the fruit shape, skin ground color, pulp texture, achenes size and acidity content of the pulp. Similar trend was observed in subgroup II.B that split into two other clusters. The first one included four accessions characterized to produce brebas of medium-small size, oblong shape, good resistance to ostiole-end cracks and with a not very juicy pulp. The second cluster was instead constituted only by "Columbro nero CS27" that produced large and particularly juicy brebas, with a globular shape and an intermediate resistance to ostiole-end cracks.

4. Discussions

The forty studied accessions are characterized by producing brebas with a very different ripening period, carpometric and qualitative characteristics. This great biodiversity has been favored by the ancient cultivation traditions of the fig tree in Calabria, the ease of propagation and the rusticity of the species, the importance of figs in the nutrition of the rural populations of this region in the past as well as the need to find alternative varieties to the "Dottato" cultivar. These forty accessions on the whole are able to guarantee a very large brebas harvesting period extending for almost seven weeks (from the end of the first ten days of June to the middle of the third ten days of July). Considering the high level of perishability of figs which consequently limits their shelf life (Michailides et al., 2008; Karabulut et al., 2009; Cantín et al., 2011), this is a very important strategic element for the development and success of a fig production chain destined for the fresh market to guarantee a continuous supply of brebas for almost two months. Furthermore, the presence of accessions with very late harvesting periods for the brebas (which practically arrives at the end of July) could allow to link to the production of real figs, guaranteeing a continuous availability of fresh figs on the market for over 4 months.

The large harvesting calendar and the good qualitative fruit characteristics, very important from the commercial point of view, are possible for both accessions with light and dark skin: "Bifera bianca CS 150", Bifera bianca CS 139", "Signorella CS 229" and Unifera bianca CS 166" for the first ones and "Bifera nera CS 119" and "Citrulara CS 31" for the second ones. This is also valid for "Bifera nera CS 103" and "Bifera nera CS 144", despite the reduced weight of figs, as their particularly early ripening (second and third decade of June) makes them interesting in commercial terms, since it is a period in which the other dark-skinned accessions do not possess ripe fruits.

Also, the carpometric and qualitative characteristics of brebas were very diversified: most of the accessions produced brebas of good size, similar or even superior to those produced by better known cultivars (Pérez Sánchez et al., 2016). It is very important

Table 6
Main quality characteristics of breba of forty autochthonous fig accessions from Calabria.

Accession	Dry matter content (%)		Total soluble solids (°Brix)		pH		Titratable acidity (g citric acid * kg^{-1})		Maturation index (TSS/TA)	
Bifera bianca CS 157	11.0	f	13.1	wx	5.95	q	0.39	d	34.0	o
Bifera bianca CS139	16.1	l-n	16.1	o-q	6.35	c	0.43	c	37.5	o
Bifera bianca CS150	13.6	r	14.6	tu	6.52	a	0.23	f-l	64.6	i-m
Bifera bianca CS158	11.2	f	12.9	x	6.54	a	0.17	no	76.6	f-k
Bifera bianca CS173	21.0	b	20.7	b	6.32	cd	0.19	l-o	108.8	ab
Bifera bianca CS180	11.3	f	10.5	y	5.93	q	0.20	k-n	52.8	mn
Bifera nera CS103	19.9	c	19.6	cd	5.54	uv	0.64	a	30.7	o
Bifera nera CS104	15.0	pq	16.7	l-p	6.03	l-o	0.17	no	101.2	b-d
Bifera nera CS106	22.4	a	20.2	bc	6.29	cd	0.19	l-o	105.6	bc
Bifera nera CS108	15.2	o-q	17.0	k-n	6.08	j-m	0.22	h-l	77.3	e-j
Bifera nera CS109	17.5	g-i	19.6	c-e	6.17	f-h	0.20	k-n	97.4	b-d
Bifera nera CS110	16.6	j-l	16.7	l-p	6.22	ef	0.20	k-n	81.8	e-g
Bifera nera CS111	17.5	g-i	17.7	i-k	6.08	j-m	0.18	m-o	101.2	b-d
Bifera nera CS119	15.7	m-o	16.5	m-p	5.69	t	0.27	e-g	62.1	j-m
Bifera nera CS123	20.1	c	18.6	f-h	6.42	b	0.15	o	122.4	a
Bifera nera CS144	20.2	c	18.8	e-g	6.07	j-n	0.52	b	36.5	o
Bifera nera CS147	19.1	de	19.6	cd	6.30	cd	0.22	h-l	89.9	d-f
Bifera nera CS148	14.6	q	16.2	o-q	6.12	h-j	0.23	f-l	71.9	g-l
Bifera nera CS175	16.3	k-n	16.0	pq	5.77	s	0.26	e-h	62.6	i-m
Citrulara CS31	17.1	h-j	16.3	n-q	5.50	v	0.21	j-n	76.0	f-k
Columbro bianco CS 198	12.9	s	13.9	uv	6.34	c	0.21	j-n	67.9	g-m
Columbro nero CS27	17.4	hi	17.3	j-m	6.02	m-p	0.23	f-l	74.6	f-l
Melenzana Pediv. CS16	16.3	k-n	15.5	q-s	5.65	t	0.24	f-k	66.5	g-m
Melenzana Staletti CZ2	19.5	cd	17.3	j-m	6.10	i-k	0.26	e-h	66.0	h-m
Mpernale CZ1	13.5	rs	16.4	n-p	6.19	fg	0.25	e-i	64.5	i-m
Niura Canna CS11	13.6	r	16.2	o-q	5.97	pq	0.27	e-g	60.0	lm
Niura Moltalto Uff. CS20	18.4	ef	18.0	h-j	6.05	k-o	0.23	f-l	77.4	e-j
Scava CS199	15.0	pq	15.1	r-t	5.59	u	0.19	l-o	77.5	e-i
Schiava CS132	19.1	de	19.2	d-f	6.22	ef	0.22	h-l	88.1	d-f
Signorella CS129	17.5	g-i	16.1	o-q	5.21	w	0.42	cd	38.9	no
Unifera bianca CS166	13.6	r	14.6	tu	6.27	de	0.21	j-n	71.1	g-l
Unifera bianca CS179	13.7	r	13.7	vw	6.08	j-m	0.54	b	25.4	o
Unifera bianca CS195	15.2	o-q	14.8	st	5.95	q	0.53	b	27.7	o
Unifera nera CS122	23.0	a	23.5	a	6.14	g-i	0.22	h-l	106.0	bc
Unifera nera CS165	16.8	i-k	18.0	h-j	6.02	m-p	0.29	e	61.5	k-m
Unifera nera CS168	16.1	l-n	16.0	pq	5.81	rs	0.25	e-i	63.8	i-m
Unifera nera CS190	18.2	fg	18.8	e-g	6.01	op	0.20	k-n	92.2	c-e
Unifera nera CS191	15.7	m-o	15.6	qr	5.87	r	0.22	h-l	69.5	g-l
Unifera nera CS193	15.6	n-p	16.9	l-o	6.30	cd	0.24	f-k	71.8	g-l
Unifera nera CS197	16.6	j-l	18.0	h-j	6.11	h-j	0.23	f-l	80.4	e-h
Sign.	**		**		**		**		**	

**Significance at $p < 0.01$; Different letters in columns represent statistically significant differences among accessions at $p < 0.05$.

as weight represents one of the most important qualitative parameter in fresh fig marketing (Çalişkan and Polat, 2008). Concerning the fruit shape, defined as the ratio between the width and the length of the fruit (IPGRI and CIHEAM, 2003), oblong brebas were produced in most of the studied accessions. Today the market tends to prefer a globular brebas rather than an oblong one, as it is more fit to packaging and transport operations (Pereira et al., 2015; Pereira et al., 2017). However, in most of the accessions that produce oblong brebas the value of the ratio between the width and the length is not so low as to hinder the packaging operations. Moreover, the studied accessions showed a low susceptibility to lateral skin cracking during fruit growth and development: it is a very important agronomic requirement as the skin cracking reduces the shelf life of fresh figs for fungal decomposition and moisture loss (Kong et al., 2013). Moreover, a large ostiole on the fig is an undesirable feature for the fresh fig trade, as it promotes the loss of moisture and represents an entrance for yeasts, bacteria and fungal pathogens, carried by insects that cause diseases such as acidification, deterioration of fermentation and endosepsis (Michailides and Morgan, 1998; Crisosto et al., 2011). For this qualitative parameter, the studied accessions also offer ample guarantees: about 2/3 of them are characterized by having rather limited ostiolar opening. Positive notes are also found in most of the accessions regarding the ease of peeling and the firmness of the fruit skin. Ease of peeling is one of the requirements most requested by consumers of fresh figs (Çalişkan and Polat, 2008) and skin firmness is a very important factor in damage reduction during packaging, transport and storage operations (Tsantili, 1990; Pereira et al., 2017) and also one of the most desired parameter in varietal selection of fresh figs (Flaishman et al., 2008). The accessions with dark skin prevailed over those with light skin: it is due to a prevalence of black skin color and green color. The color variation depends on pigment (anthocyanins, chlorophylls and carotenoids) concentration (Solomon et al., 2006). Anthocyanin synthesis and of chlorophyll degradation occur in the peel mainly in the second period of fruit growth, when it ripens, the sugars accumulate and other important qualitative traits are characterized (Crane and Baker, 2019). The skin color of fresh figs is a visual parameter that growers and consumer use mainly to test the quality and the optimal ripening stage (Pérez-Sánchez et al., 2016). Generally, the consumer preferences are oriented towards figs of light green or dark purple color compared to those with intermediate colors. Related to it, most of the studied accessions produce brebas with a color that fully meet market demands (Çalişkan and Polat, 2012a, 2012b). The found wide range of sugar content on figs is interesting as it evidences the possibility to significantly diversify the production of figs, satisfying the demands of the different markets and diet regimes. Though a variability among accessions was noted

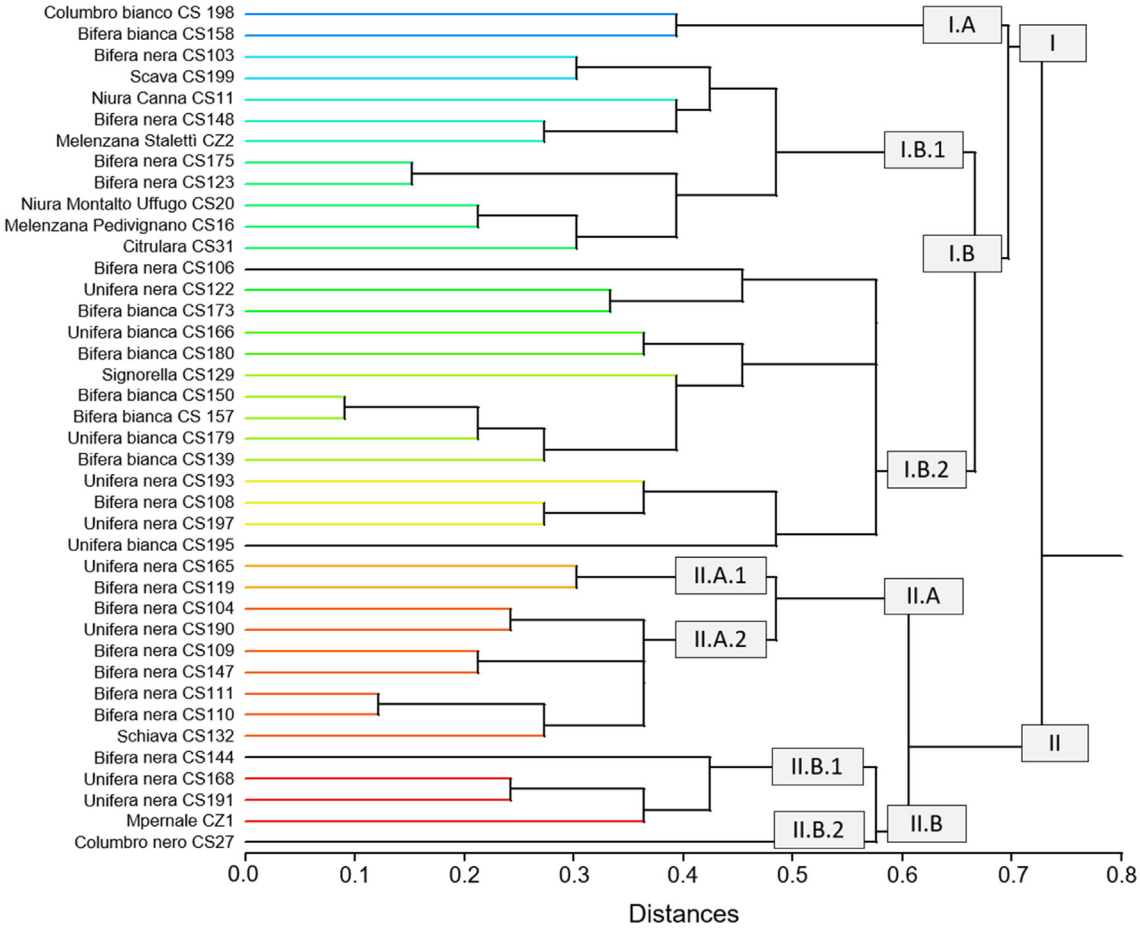

Fig. 1. Cluster analysis, based on the statistical analysis of 33 morphological traits of breba of studied 40 autochthonous fig accessions, based on the distance 'percent' and the 'complete linkage method'.

for pH values, the value of 6, measured in most of these, is a good result for the sensorial quality, influencing the perception of sweetness on fruits (Pereira et al., 2015; Gunness et al., 2009). The variability of TA denoted some differences among brebas: in general, these results evidenced a higher acidity of pulp than those observed in other cultivars cultivated in Spain (Pereira et al., 2015; Núñez-Gómez et al., 2021). The perception of sweetness on fruits is linked to the measured TSS/TA: this ratio is used for cultivar selection as index of fruit quality and consumer satisfaction (Çalişkan and Polat, 2008). Cluster analysis evidenced a great variability for ripening period and morphological and qualitative characteristics of brebas among accessions, that agrees with the results of the molecular characterization conducted using SSR markers (Costa et al., 2017). Moreover, it has evidenced that the terms "Bifera bianca" "Bifera nera", "Unifera bianca" and "Unifera nera" indicate fig accessions, belonging to the common type, with very diversified phenological and bio-agronomic characteristics, united that guarantee one ("Unifere") or two ("Bifere") fruiting per year in Calabria, as well as in other parts of the Mediterranean Basin (Giraldo et al., 2010). From the study of the two accessions "Melenzana Staletti CZ2" and "Melenzana Pedivignano CS16", it resulted that the term "Melenzana" refers to accessions of figs belonging to the San Pedro type, with quite diversified characteristics, united only by the fact that they produce good quality brebas, of medium size, of oblong shape (similar to that of an aubergine), with a particularly long neck, with dark-coloured skin and aromatic pulp. Similarly, the two accessions of "Niura Canna CS11"and "Niura Moltalto Uffugo CS20" were shared common traits that can be traced back to the term "Niura". The two accessions "Columbro nero CS27" and "Columbro bianco CS 198" were instead diversified for the peel colour and also for many external and internal morphological characteristics, confirming that with the term "Columbro" very different accessions of figs are denominated in Italy, generally belonging to the San Pedro type, united only for the produced large-sized brebas, globular in shape, with soft skin and particularly juicy pulp.

5. Conclusions

Awaiting genetic improvement programs that make new cultivars available to growers, the only way to select fig varieties suitable for fruit production for the fresh market is to exploit the existing genetic diversity, identifying the best genotypes within it. The accessions evaluated with this study showed a production of brebas with very diversified ripening period and morphological and qualitative characteristics. It makes this material very important not only for its possible use in genetic improvement programs but also for its immediate use to create new commercial orchards for the production of brebas. A remarkable number of these accessions of figs is, in fact, capable of producing brebas with high-quality characteristics, that they can compete with those produced by other more widespread cultivars. Moreover, they offer a very wide harvesting period in general, whereas the presence of accessions with very early fruit ripening period is an important characteristic for the Mediterranean Basin, where brebas ripened at the start of June are very rare.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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