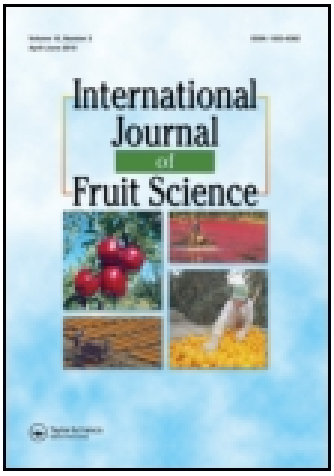

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Yield and Fruit Quality Characterization of Eight Old Sicilian Apple Cultivars

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In this trial, we examined the quality of eight old Sicilian apple cultivars ('Cannamelo', 'Cardinale', 'Gelata Cola', 'Gelata', 'Granatino', 'San Giuseppe', 'Virticchiaro', 'Zitella') and a commercial one ('Annurca' traditional clone) through bio-agronomic performances and chemical-physical analyses. We also analyzed flowering time, ripening time, pomological characteristics, and generated a specific descriptor list that indicates a great variability among the cultivars. The data obtained showed interesting characteristics in 'Granatino', 'Virticchiaro', and 'Zitella', such as total soluble solid, fruit size, peel cover color, yield efficiency, and crop load.

KEYWORDS Malus domestica*, germplasm, descriptor list, soluble solids, flesh firmness, titratable acidity, cover color*

INTRODUCTION

The development of intensive apple (*Malus domestica* Borkh.) growing, based on the use of low-vigor rootstocks, accounts for the almost complete extinction from culture of many ancient cultivars, obsolete from an agronomic and productive perspective, resulting in a great biodiversity loss. Some of these old cultivars are characterized by specific flavors and aroma, and at the same time, by interesting quality features (Bounous et al., 2006; Guarrera et al., 2008). Additionally, in some cases, they possess good disease resistance (Bignami et al., 2003; Aldwinckle et al., 1999; Gradinariu et al., 2003; Kellerhals et al., 2004) along with a good adaptation to varied climatic

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and soil conditions. These genetic resources are also critical in identifying the most important quality traits for future breeding programs.

Today there is a strong interest in ancient fruits. Since the late 1980s, there has been a market demand for distinct and recognizable products characterized by a link to territory and tradition (Inglese and Caruso, 2006). The results of these actions have been the creation of large collections of apple genotypes (Watkins and Smith, 1982; Watkins and Sansavini, 1984) with safeguard programs based on *ex situ* preservation (Fideghelli, 2006). This trend is in line with governmental policies, such as the Stockholm declaration (1972), the Biological Diversity Convention of Rio De Janeiro (1992), and the Italian Convention Biodiversity on (1994) (Grassi et al., 2003). Many studies were conducted in several countries (Gradinariu et al., 2003; Volz et al., 2006; Aldwinckle et al., 1999) and in Italy to valorize local apple genetic resources in Emilia Romagna (Buscaroli and Ventura, 1991), Piedmont (Radicati et al., 1991; Bounous et al., 2006; Cavanna et al., 2009), Lombardy (Eccher et al., 2006; Lo Scalzo et al., 2006), Tuscany (Federico et al., 2008), and Sicily (Continella et al., 2006; Gentile et al., 2006) and emphasized the importance of the characterization of germplasm species. In Sicily, apple cultivation is very ancient (Nicosia, 1735). Many old genotypes are of local origin or were acquired a very long time ago but are localized, such as isolated exemplars, in particular in the mountainous inland areas where there is a limited use of agricultural resources, there has been a slow loss of genetic variability, such as in the Etna district (Continella et al., 2006) and in the Madonie mountains (De Michele, 1992).

Identification and characterization of the regional fruit germplasm represents an important strategy to collecting genetic resources of great value for the local environment (Fideghelli, 2007), and it is crucial to select the best ones for market appreciation or industrial transformation. To study the commercial potential of these apple fruits, consumer acceptance (Castellari et al., 2001) must be analyzed, but essentially the organoleptic characteristics define fruit quality (Hoehn et al., 2002).

The aim of this trial was to analyze the pomological and qualitative characteristics of eight old cultivars of Sicilian selections using bio-agronomic parameters and chemical and physical analyses. Ancient apple fruits were compared with 'Annurca', the oldest Italian cultivar, still with a great economic value.

MATERIALS AND METHODS

The trial was conducted near Caltavuturo (37° 49′ N and 850 m a.s.l.) in central Sicily, Italy, in an experimental field, in 2009. Plant material consisted of 24 11-year-old trees of 8 old genotypes, also generally called "old cultivars"—'Cannamelo', 'Cardinale', 'Gelata Cola', 'Gelata', 'Granatino', 'San Giuseppe', 'Virticchiaro', and 'Zitella'. They were collected from different Sicilian areas and grafted on M9 rootstock along with five trees of the

'Annurca' (Traditional clone) cultivar. 'Annurca' was selected as a reference genotype because it is an ancient cultivar largely diffused in the South of Italy, with specific organoleptic characteristics appreciated in a niche market (Grassi and Limongelli, 2000). Today this cultivar has obtained the GPI (Protected Geographical Indication) brand standard that permits it to have a new market placement (Rossi and Socciarelli, 2003).

In the field, trees were planted on one north-south row with an inter-trees spacing of 1.5 m and 4 m between rows. The training system was a central leader, and those trees were divided into three replicates per genotype. The soil is classified as a sandy clay loam (53.3% of sand, 17.6% of silt, and 29.1% of clay) with pH 7.3 and 1.8% active carbonates. The irrigation system was drip irrigation and trees received a conventional cultural care under organic agriculture criteria. Chilling hours accumulated were 700, from leaf drop until the end of February.

Fruits were collected at commercial ripening in October using ground color and starch pattern index as maturity indexes. A 50-fruit sample for each tree (three replicates per cultivar) was submitted to pomological and chemical and physical analyses.

Following International Board of Plant Genetic Resources (IBPGR) (Watkins and Smith, 1982) and varietal registry (Sansavini et al., 1986) pomological charts updated using UPOV guidelines (International Union for the Protection of New Cultivars of Plants, 2005), a specific descriptor list was generated to evaluate fruit quality and to discriminate the different cultivars. The characteristics analyzed were: blooming time, ripening time, general shape (cylindrical-waisted, waisted, conic, ovoid, cylindrical, ellipsoid, globose, or obloid), ribbing (absent or weak, moderate, strong), depth (shallow, medium, deep), and width (narrow, medium, or broad) of stalk cavity and of eye basin, length (very short, short, medium, long, very long) and thickness (thin, medium, thick) of stalk, aperture of locules (closed or slightly open, moderately open, fully open), number of lenticels (few, medium, many), size of lenticels (small, medium, large), ground color (not visible, whitish-yellow, yellow, whitish-green, yellow-green, green), cover color hue (orange-red, pink-red, purple-red, brown-red), intensity (light, medium, or dark), pattern (only solid flush, solid flush with weakly defined stripes, solid flush with strongly defined stripes, weakly defined flush with strongly defined stripes, only stripes, no flush, flushed and mottled, flushed, striped and mottled), width of stripes (narrow, medium, or broad), and color of flesh (white, cream, greenish, pinkish, reddish).

Biometrical (height, diameter, height/diameter ratio, weight) and chemical and physical characteristics were also observed: flesh firmness (kg/cm^2), total soluble solid (TSS), tritatable acidity (TA), and TSS/TA ratio. Weight was determined by digital scale; longitudinal and transversal diameter by digital caliper TR53307 (Turoni, Forlì, Italy); flesh firmness by digital penetrometer TR5325 (Turoni, Forlì, Italy); TSS by digital refractometer Atago Palette PR-32 (Atago Co., Ltd, Tokyo, Japan), titratable acidity expressed in g/l of

malic acid and pH using a CrisonS compact tritator (Crison Instruments, SA, Barcelona, Spain). Digital images were used to determine percentage and intensity of peel red color. In particular, we used an algorithm that converts images from RGB to CIE L*a*b* format, extracts the fruit from the image (removing the image background), separates the total fruit area into two sub regions, cover color (closer to red) and ground color (closer to green) according to an adjustable green–red threshold, and quanties color characteristics of each region as the weighed distance of each pixel in the image from pure green (ground color) or pure red (cover color). The output is an index for the cover color ranging from 0 (no red) to 1 (red). Percentage of cover color was calculated dividing the number of pixels of the red region by the number of pixels of the entire fruit area. Taste and aroma were evaluated by an empiric scale from 1 (weak) to 5 (strong). Moreover, yield and number of fruit per tree and, after fruit harvest, trunk circumference at ~15 cm above the graft union, were measured. Yield efficiency and crop load were expressed as kilogram or number of fruit per trunk cross-sectional area (TCSA).

The qualitative, productive, and sensory data were submitted to analysis of variance (one-way ANOVA), with samples as effects. The significance of these effects was evaluated by F-tests.

RESULTS AND DISCUSSION

Full bloom could be considered similar to Golden Delicious, according to De Michele (1992) while the start of flowering showed differences among the cultivars (Table 1). The first to flower were 'Annurca', 'Zitella', 'Cannamelo', 'Gelata Cola', and 'Virticchiaro' from early to mid-April followed by 'Granatino', 'Gelata', and 'S. Giuseppe' from mid to late April. Because of the harvest date, all the examined genotypes could be considered among the group of winter cultivars (Table 1). Although all the cultivars were edible from mid-August, it is a habit to harvest in October when the

TABLE 1 Blooming and Ripening Period of the Nine Cultivars Under Observation

Cultivars	Blooming period	Ripening period	Harvest date
Annurca	1st half of April	1st half of October	November 19
Gelata Cola	1st half of April	1st half of October	October 7
Virticchiaro	1st half of April	2nd half of October	November 19
Cardinale	1st half of April	2nd half of October	November 13
Granatino	2nd half of April	1st half of October	October 7
Zitella	1st half of April	1st half of October	October 7
Gelata	2nd half of April	1st half of October	October 7
S. Giuseppe	2nd half of April	1st half of October	October 7
Cannamelo	1st half of April	1st half of October	October 11

fruits show their best characteristics. Harvest started with 'Annurca', 'Gelata Cola', 'Granatino', 'Zitello', 'Gelata', 'S. Giuseppe', and 'Cannamelo' from mid-October followed by the others harvested in late October.

The descriptor list indicates a great variability among the cultivars (Table 2). As for the general shape, genotypes showed a variability of fruit features that varied from globose to obloid and only in one case cylindrical waisted. Ribbing was absent because the diameter was circular for all cultivars except for 'Gelata Cola', 'Granatino', and 'Cannamelo'. Four cultivars presented medium depth of stalk cavity ('Gelata Cola', 'Cardinale', 'Gelata', and 'Cannamelo'), four ('Annurca', 'Granatino', 'Zitella', and 'S. Giuseppe') deep and only one ('Virticchiaro') shallow. Most cultivars showed medium width of stalk cavity except for 'Annurca', 'Virticchiaro', and 'Zitella' (broad) and for 'Granatino' (shallow). The same was for the depth of eye basin that was shallow for most cultivars except for 'Cardinale' and 'Gelata'(medium), whereas the width of eye basin was medium for five cultivars ('Gelata Cola', 'Cardinale', 'Gelata', 'Zitella', and 'S. Giuseppe') and broad for the last four ('Annurca', 'Virticchiaro', 'Granatino', and 'Cannamelo'). Length of stalk was short for four cultivars, very short for three, and long only for one. Five cultivars had a thin stalk, whereas four had a medium one. Aperture of locules was slightly open in five ('Annurca', 'Virticchiaro', 'Cardinale', 'Gelata', and 'Cannamelo') cultivars, moderately open in two ('Granatino' and 'Zitella'), and fully open in two ('Gelata Cola' and 'S. Giuseppe'). Number and size of lenticels were equal for all cultivars except for 'S. Giuseppe' that showed medium sized ones (data not presented in the table).

Ground color was green for all cultivars, whereas 'Cannamelo', 'Gelata Cola', and 'Gelata' showed a yellow-green color. Cover color distribution had the largest surface in 'S. Giuseppe' and 'Cannamelo' followed by 'Granatino', 'Virticchiaro', and 'Annurca'. Cover color hue was red in 'Annurca', orange-red in 'Granatino' and 'S. Giuseppe', purple-red in 'Cannamelo', pink-red in 'Zitella', absent in 'Gelata Cola', 'Cardinale', and 'Gelata', and brown-red in 'Virticchiaro'. The intensity of cover color was light in 'Granatino', medium in 'Annurca', 'Zitella', and 'S. Giuseppe', and dark in 'Virticchiaro' and 'Cannamelo'. 'Annurca', 'Virticchiaro', 'S. Giuseppe', and 'Cannamelo' showed a solid flush with weakly defined striped pattern, whereas 'Granatino' showed a weakly defined flush with strongly defined stripes, 'Virticchiaro' showed only solid flush, and 'Zitella' was flushed and mottled; all these cultivars, except 'Zitella', have medium width of stripes. Finally, color of the flesh was greenish for all cultivars except for 'Annurca' and 'Gelata Cola' that have white pulp (Table 3).

Fruit size showed differences among the examined cultivars (Table 4). 'Cannamelo', 'Granatino', and 'Gelata' fruits showed the best size followed by 'Virticchiaro', 'Annurca', 'S. Giuseppe', and 'Zitella'. All these fruits have the size characteristics of the most diffused commercial apple varietal groups. 'Cardinale' and 'Gelata Cola' produced very small fruits that did

TABLE 2 Pomological Traits of the Nine Cultivars Under Observation Based on the Descriptor List

CV	General shape	Ribbing	Depth of stalk cavity	Width of stalk cavity	Depth of eye basin	Width of eye basin	Length of stalk	Thickness of stalk	Aperture of locules
Annurca	Globose	Absent	Deep	Broad	Shallow	Broad	Very short	Medium	Slightly open
Gelata Cola	Cylindrical waisted	Moderate	Medium	Medium	Shallow	Medium	Very short	Medium	Fully open
Virticchiaro	Obloid	Absent	Shallow	Broad	Shallow	Broad	Short	Medium	Slightly open
Cardinale	Globose	Absent	Medium	Medium	Medium	Medium	Long	Thin	Slightly open
Granatino	Obloid	Moderate	Deep	Narrow	Shallow	Broad	Medium	Thin	Moderately open
Zitella	Obloid	Absent	Deep	Broad	Shallow	Medium	Very short	Thin	Moderately open
Gelata	Obloid	Absent	Medium	Medium	Medium	Medium	Short	Medium	Slightly open
S. Giuseppe	Globose	Absent	Deep	Medium	Shallow	Medium	Short	Thick	Fully open
Cannamelo	Globose	Moderate	Medium	Medium	Shallow	Broad	Short	Thick	Slightly open

TABLE 3 Fruit Color and Cover Color Characteristics Based on Descriptor List and Color Index

		Cover color characteristics					
CV	Ground color	Relative area (%)	Hue	Intensity	Pattern	Width of stripes	Color of flesh
Annurca	Yellow green	75.21 ± 6.21	Red	Medium	Solid flush with weakly defined stripes	Medium	White
Gelata Cola	Yellow green	—	—	—	—	—	White
Virticchiaro	Green	82.29 ± 4.25	Brown red	Dark	Only solid flush	—	Greenish
Cardinale	Green	—	—	—	—	—	Greenish
Granatino	Green	82.65 ± 5.21	Orange-red	Light	Weakly defined flush with strongly defined stripes	Medium	Greenish
Zitella	Green	25.22 ± 3.21	Pink-red	Medium	Spotted	—	Greenish
Gelata	Yellow green	—	—	—	—	—	Greenish
S. Giuseppe	Green	89.21 ± 6.05	Orange-red	Medium	Solid flush with weakly defined stripes	Medium	Greenish
Cannamelo	Green	84.22 ± 4.21	Purple-red	Dark	Solid flush with weakly defined stripes	Medium	Greenish

—: Not present.

TABLE 4 Fruit Quality Dimensional Characteristics

Qualitative characteristics	Weight (g)	TD (mm)	LD (mm)	TD/LD
Annurca	121.73 ± 13.86	66.90 ± 3.44	52.64 ± 2.85	1.27 ± 0.026
Gelata Cola	65.91 ± 8.54	54.73 ± 10.97	47.32 ± 3.47	1.15 ± 0.249
Virticchiaro	127.9 ± 30.11	67.02 ± 5.83	50.58 ± 4.52	1.32 ± 0.142
Cardinale	85.53 ± 16.03	44.87 ± 4.98	39.54 ± 4.09	1.13 ± 0.104
Granatino	148.41 ± 28.25	75.80 ± 4.01	54.72 ± 12.53	1.38 ± 0.218
Zitella	104.08 ± 26.68	63.74 ± 6.63	48.86 ± 6.62	1.30 ± 0.084
Gelata	134.23 ± 11.52	72.49 ± 3.82	52.02 ± 4.16	1.39 ± 0.075
S. Giuseppe	94.2 ± 18.23	60.02 ± 4.75	48.41 ± 3.41	1.23 ± 0.083
Cannamelo	132.31 ± 46.34	67.96 ± 8.99	56.84 ± 6.63	1.19 ± 0.069

not reach the standard for the fresh market (Dalpiaz et al., 2005) because they showed an inferior size in respect to the second commercial size for apple fruit (Reg. CE n.85/2004). For this reason these fruits can be placed only on the local market. The best cultivars could be placed, for commercial class reached, also on the OGD (organized great distribution) market. The length/diameter ratio was similar for all cultivars.

Chemical-physical characteristics indicated interesting features in some cultivars (Table 5). TSS values ranging from 13.85 to 16.20 °brix were good for all cultivars, whereas TA ranging from 5.42 to 17.57 g/l and 'Cannamelo', 'Gelata', 'Granatino', and 'S. Giuseppe' showed very high values compared to the more diffused commercial cultivars (Angelini, 2009). Consequently, the TSS/TA ratio, which described fruit pleasantness, was more balanced in 'Granatino' and 'Cannamelo', whereas in 'Annurca', 'Cardinale', 'Gelata Cola', 'Virticchiaro', and in 'Zitella' it was sub-acidic and in 'Gelata' and 'S. Giuseppe' it was more acidic.

The starch index, showed similar values and indicated that fruits were harvested at the same maturity stage for all cultivars. The highest values of cover color index were observed in 'Annurca', 'S. Giuseppe', 'Cannamelo', and 'Virticchiaro', confirming the data reported on the descriptor list.

Flesh firmness was adequate for all cultivars, but 'Cannamelo', 'Gelata Cola', 'Gelata', and 'Zitella' showed the lowest values. This indicates the difficulties to introduce these cultivars on the GDO market.

All the cultivars under observation had a relevant yield per tree, ranging from 12.34 to 17.32 kg (Table 6). Number of fruits per tree showed differences among the cultivars. In fact, 'Gelata' produced the fewest fruits followed by 'Granatino'. Average values were observed on 'Annurca', 'Cannamelo', 'Granatino', 'Virticchiaro', and 'Zitella'. 'S. Giuseppe', 'Gelata Cola', and 'Cardinale' showed the best yield values. The high number of fruits produced by 'Gelata Cola' compared to its yield per tree indicated a small fruit size, confirmed by the elevated crop load and the low yield efficiency. The same is to be said in 'Cardinale' for which the high value of yield efficiency was justified by the elevated number of fruits instead of their size. On the contrary, 'Granatino' and 'Virticchiaro' showed high yield efficiency thanks to their crop load and fruit size. 'Cannamelo' and 'Gelata' had low yield efficiency explained with the limited number of fruits. 'S. Giuseppe' had high yield but low yield efficiency and low crop load may be caused by a smaller fruit size. 'Annurca' and 'Zitella' had a balanced ratio between tree canopy, number, and fruit size showing good values of yield efficiency and crop load.

CONCLUSIONS

The aim of this work, to evaluate trees and characterize the fruit of eight ancient Sicilian apple cultivars in order to determine their quality, was met.

TABLE 5 Fruit Chemical-Physical Characteristic

Quality characteristics	TSS (°Brix)	TA ($g \cdot 1^{-1}$)	TSS/TA	Firmness ($kg \cdot cm^2$)	Starch pattern index	Cover color index
Annurca	15.00 ± 0.26	7.93 ± 0.13	1.89 ± 0.01	8.03 ± 0.02	0.856 ± 0.002	0.854 ± 0.002
Gelata Cola	14.65 ± 0.35	7.53 ± 0.07	1.95 ± 0.12	3.93 ± 0.43	0.845 ± 0.001	–
Virticchiaro	16.01 ± 0.29	9.82 ± 0.29	1.63 ± 0.08	7.72 ± 0.88	0.862 ± 0.003	0.845 ± 0.002
Cardinale	14.60 ± 0.43	5.43 ± 0.10	2.69 ± 0.24	6.01 ± 1.00	0.872 ± 0.002	–
Granatino	14.40 ± 0.71	14.40 ± 0.71	1.03 ± 0.05	4.31 ± 0.27	0.843 ± 0.003	0.831 ± 0.004
Zitella	14.80 ± 0.14	14.80 ± 0.14	1.82 ± 0.08	3.96 ± 0.51	0.854 ± 0.003	0.832 ± 0.005
Gelata PA	16.20 ± 0.42	16.20 ± 0.42	0.92 ± 0.03	3.27 ± 0.26	0.862 ± 0.004	–
S. Giuseppe	13.85 ± 0.49	13.85 ± 0.49	0.81 ± 0.07	4.90 ± 0.59	0.872 ± 0.004	0.851 ± 0.004
Cannamelo	15.25 ± 0.64	15.25 ± 0.64	1.11 ± 0.12	3.89 ± 0.53	0.863 ± 0.005	0.845 ± 0.001

—: Not present.

TABLE 6 Production of the 8 Apple Varieties Under Observation

	Yield per tree (kg)	No. of fruit per tree	Yield efficiency (kg/cm^2 TCSA)	Crop load (No. of fruit/cm^2 TCSA)
Annurca	15.25 ± 1.21	125.43 ± 5.23	0.24 ± 0.02	2.03 ± 0.43
Gelata Cola	12.34 ± 1.42	155.32 ± 4.32	0.2 ± 0.03	2.67 ± 0.78
Virticchiaro	16.27 ± 1.05	125.21 ± 5.98	0.25 ± 0.04	2.05 ± 0.54
Cardinale	16.12 ± 1.09	185.85 ± 3.87	0.27 ± 0.01	2.15 ± 0.34
Granatino	17.32 ± 1.32	112.54 ± 5.65	0.27 ± 0.02	2.08 ± 0.46
Zitella	15.98 ± 1.08	136.65 ± 5.89	0.25 ± 0.03	2.15 ± 0.35
Gelata PA	14.12 ± 1.06	99.43 ± 6.02	0.2 ± 0.04	1.86 ± 0.28
S. Giuseppe	15.21 ± 1.21	152.98 ± 3.21	0.21 ± 0.05	1.74 ± 0.54
Cannamelo	16.43 ± 1.05	142.12 ± 4.54	0.18 ± 0.01	1.44 ± 0.64

The descriptor list generated from UPOV and IBPGR guidelines was useful to differentiate the examined cultivars through fruit characteristics. Analyzed data showed interesting features in 'Granatino', 'Virticchiaro', 'Cannamelo', and 'Zitella', such as TSS, fruit size, and peel cover color. 'Granatino' had an attractive red cover color, whereas 'Zitella' showed a flushed and mottled pink cover color. 'Granatino', 'Virticchiaro', and 'Zitella' had good values of yield efficiency and crop load, important features for economic sustainable cultivation. Even though apple cultivation in Sicily has a low economic impact compared to the best (vocated) areas of Northern Italy, in some mountainous inland areas of Palermo and Catania, apple germplasm is widely diffused with economic, historic, cultural, and landscape interests. In this way, a conservation and evaluation activity, in situ and extra situ, of ecotypes or autochthonous genotypes is decisive. These activities could conserve the regional biodiversity and implement the consumer needs that are oriented towards typical regional products.

The evaluation of these ancient cultivars has shown a variability of phenotypical features and qualitative characteristics, some of which could be interesting as a genetic resource. There should be a re-evaluation of some of these fruits for placement on specific local markets.

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