Scientia Horticulturae 217 (2017) 217–225

Contents lists available at ScienceDirect

Scientia Horticulturae

journal homepage: www.elsevier.com/locate/scihorti

Horticultural performance of 23 Sicilian olive genotypes in hedgerow systems: Vegetative growth, productive potential and oil quality

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A R T I C L E I N F O

Article history:
Received 1 October 2016
Received in revised form 24 January 2017
Accepted 27 January 2017

Keywords:
Arbequina
Cultivar evaluation
Germplasm
Olea europaea L.
Super high density orchards
Yield

A B S T R A C T

The super high density (SHD) model is a new olive growing system characterized by earlier and higher yields, fully mechanized harvesting and reduced orchard management costs. Until recently all commercial SHD orchards were planted primarily with three varieties: 'Arbequina', 'Arbosana' and 'Koroneiki'. To increase variety diversity, broaden available olive oil chemical and organoleptic profiles, and olive oils for marketing, minor local varieties should be evaluated for adaptability to the SHD system. This study compares multiple Sicilian native genotypes to the three current cultivars 'Arbequina', 'Arbosana' and 'Koroneiki'. The cumulative fruit and oil production, trunk-cross section area, canopy volume, alternate bearing behavior and oil quality were evaluated in a SHD system. Among the standard cultivars 'Koroneiki' had significantly higher and 'Arbequina' average productivity respectively compared to earlier reports and was chosen as the reference for evaluating the performance of the Sicilian genotypes. Many of the genotypes investigated had olive and oil yields equal to or higher than 'Arbequina'; 'Abunara' and 'ADE' had very high productivity. 'Abunara' produced a medium-high quality oil. The 'KALAT' selection had high productivity and low vigor, and therefore high productive efficiency. However, the oil polyphenols were low. The 'Cerasuola' and 'Piricuddara' cultivars had good productivity and a very high quality oils. These results confirm the need to evaluate and preserve local genetic resources as a strategy for improving SHD olive management and increasing olive cultivar and oil diversity.

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1. Introduction

In the last two decades, the olive oil industry has experienced major production changes. The newer olive producing countries, as well as many traditional olive growing countries, are adopting the super high density (SHD) system, that facilitates mechanized harvesting and pruning. The SHD plantings sharply reduce management and production costs compared to the lower yielding hand-harvested traditional orchards (Deidda et al., 2006; Godini, 2009).

Currently SHD production utilizes three specific cultivars characterized by early bearing, high and constant productivity, and low vegetative vigor: the Spanish 'Arbequina' and 'Arbosana' and the Greek 'Koroneiki' (Avidan et al., 2011; Baldoni and Belaj, 2009; Bellini et al., 2008; Rallo et al., 2008; Tous et al., 2003). The consequence of widespread adoption of the SHD system is the loss of the local cultivars that produce high quality oils using traditional methods. The final result will be a loss of olive germplasm and oil diversity. To prevent this loss of cultivar and oil diversity, local cultivars should be evaluated for their adaptability to SHD production.

Among the evaluations thus far Farinelli and Tombesi (2015) compared the growth and productivity of four Italian varieties relative to the 'Arbequina' cultivar. They reported Italian cultivar 'Maurino' suitable for SHD orchards. In Apulia, various trials, comparing Italian varieties for suitability to the SHD system (Bellomo and Godini, 2003; Camposeo et al., 2008; Camposeo and Giorgio, 2006; Godini et al., 2006a, 2006b), found only 'Urano®' suitable for SHD production. All other varieties were unsuitable due to excessive vigor, spreading habit, late bearing and/or susceptibility to fruit bruising (Camposeo and Godini, 2010).

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http://dx.doi.org/10.1016/j.scienta.2017.01.046
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Table 1
List of the 6 major Sicilian cultivars, the 15 minor Sicilian cultivars, the 2 selections and of the 3 international cultivars planted in 2006 in a high-density system (1140 t/ha).

Main cultivars	Minor cultivars	Selections	International cultivars
Biancolilla	Abunara	ADE	Arbequina
Cerasuola	Bottone di gallo	KALAT	Arbosana
Moresca	Brandofino		Koroneiki
Nocellara del Belice	Castriciana		
Tonda iblea	Cavalieri		
Oglialora Messinese	Crastu		
	Erbano		
	Giarraffa		
	Minuta		
	Nasitana		
	Nerba		
	Nocellara Messinese		
	Olivo di Mandanici		
	Piricuddara		
	Vaddarica		

In the traditional olive growing countries, many “minor” cultivars are produced, some represented by as little as a single wild ancient tree (Rallo, 2005; Zohary and Spiegel-Roy, 1975; Sedgley and Wirthensohn, 2000). Fortunately, many have been collected, conserved and characterized (Alba et al., 2009; Bracci et al., 2009; Caruso et al., 2007, 2014b; Corrado et al., 2009; Erre et al., 2010; La Mantia et al., 2005; Marchese et al., 2016a,b; Marra et al., 2013; Muzzalupo et al., 2007; Rao et al., 2009; Rotondi et al., 2003; Sensi et al., 2003). However, this large genetic collection of native genotypes has not been evaluated for SHD production. The objective of this trial was to evaluate the suitability of 21 Sicilian cultivars and two new selections for SHD production. The horticultural, vegetative and productive performance of these 23 genotypes was compared to those of three standard SHD cultivars ‘Arbequina’, ‘Arbosana’ and ‘Koroneiki’, grown within the same environment. The final objective was to identify genotypes that are suitable for high density systems while providing high quality oils which also diversify the oil chemical profiles.

2. Materials and methods

2.1. Experimental site

The experimental orchard was planted with one-year-old self-rooted 50–70 cm plants in February 2006 in a traditional olive-growing area in southern Italy (Sicily) (37°31′ N, 13°03′ E and at 56 m asl). The typically Mediterranean climate is characterized by hot dry summers and mild winters with an annual average rainfall of 500–600 mm. The soil was a typical Red Mediterranean soil with 69% sand, 13% silt and 18% clay, 7.9 pH and 1.1% dry matter. The three “international” cultivars, ‘Arbequina’, ‘Arbosana’ and ‘Koroneiki’, were the SHD controls for six major Sicilian cultivars, 15 minor or neglected Sicilian cultivars (Caruso et al., 2007) and two genotypes selected by the Department of Agricultural and Forest Sciences of the University of Palermo (Table 1). Growth and production were monitored from 2009 to 2015.

2.2. Experimental design and orchard management

The 25 plants per cultivar/genotype, spaced 2.5 × 3.5 m (about 1140 trees/ha), were planted in a single north-south row. The trees were pruned lightly during the first 5 years after planting (YAP) to facilitate evaluation of vigor and early bearing. Only trunk branches below 60 cm from the soil were pruned. During the 2011 dormant season the trees were mechanically topped and hedged and trained to a free palmate shape to facilitate mechanical harvesting with an over the row straddle harvester. Weekly irrigation from July through mid-September was delivered by five self-compensating in-line drippers per plant spaced at 50 cm intervals which delivered 1.6 l/h. The total seasonal application rate was 800 m^3/ha/year.

2.3. Measurements

From the 3th to the 7h YAP yield per tree was measured on 8 randomly selected trees per genotype.

The Alternate Bearing Index, ABI, which quantifies the degree of annual yield variation was then calculated for the 4th to the 7th for each cultivar/genotype (Hoblyn et al., 1936):

$$\mathrm{ABI} = \frac{\sum_{t=2}^{n}\left(\frac{|y_t - y_{t-1}|}{y_t + y_{t-1}}\right)}{n-1}$$

where y equals yield in a corresponding year t, and n the total number of years. The unit free ABI, ranges from 0 and 1, with ABI = 0 designating no alternate bearing behavior and ABI = 1 total alternate bearing (Wood, 1989).

At the end of each growing season, trunk cross-section area (TCSA, cm^2) was measured at 50 cm above the ground level. The average TCSA and yield per ha (t) were used to calculate crop efficiency; CE = kg of fruit/cm^2 of TCSA. In the 2010 season, before the mechanical pruning was started, 12 plants per genotype were monitored for growth. Canopy height (H), width (L_1) and depth (L_2) were used to calculate total canopy volume (canopy volume = $L_1 \times L_2 \times H$). Immediately postharvest the olives fruits were washed, crushed by a hammer mill, the paste mixed at 20–25 °C for 20 min and the oil extracted by a continuous three-phase centrifuge system (Pieralisi M.A.I.P. S.p.A. model M3, Jesi, Italy). The resulting oil percentage and yield per ha were used to calculate oil yield per ha. Oil samples were stored in the dark at 11 °C until analysis using the European Communities official methods (Reg. EEC no. 2568/91).

2.4. Virgin olive oil analysis

Oil samples were analyzed for free acidity, peroxide value, polyphenol content, and fatty acid composition.

Total polyphenols were analyzed using the Folin–Ciocalteau colorimetric method (Arcoleo et al., 2006; Di Stefano and Guidoni, 1989; Picerno et al., 2003). The quantities were expressed as gallic acid ppm (Slinkard and Singleton, 1977). The fatty acid composition was determined by gas chromatographic analysis of the relative methyl esters, following the Mineo et al. (2007) protocol.

2.5. Statistical analysis

Statistical analysis of the data (ANOVA) was done using Systat (SYSTAT Software Inc., Chicago, IL). The Least Significant Differences (LSD) at $P \leq 0.05$ were calculated to separate means.

3. Results

3.1. Productivity

Three years after planting (2009), ‘Olivo di Mandanici’ was the most productive cultivar producing 5.6 t/ha followed by the three standard cultivars (‘Arbosana’, ‘Koroneiki’ and ‘Arbequina’) which collectively averaged 3.1 t/ha (Fig. 1a). The Sicilian cultivar ‘Minuta’ produced 2 t/ha while lower values were recorded in all the remaining cultivars. In 2010, production increased in all the cultivars (Fig. 1b). The control ‘Koroneiki’ produced 31 t/ha, significantly higher than all the other cultivars followed by ‘Bottone di Gallo’, ‘ADE’, ‘Abunara’, ‘Olivo di Mandanici’ and ‘Arbequina’ all with similar production of 14–15 t/ha. Slightly lower yields per ha

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