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Abstract: An intense survey of the Sicilian's olive growing areas for autochthonous germplasm, mainly represented by centennials olive trees (Olea europaea var. europaea L.) apparently older then III centuries, started at the beginning of the 1980s and resulted in the selection of more than 150 cultivars and accessions. This germplasm was propagated in a nursery, by grafting onto seedlings of Olea europaea L., and planted in an experimental orchard, in an olive district located in the South-west of the Island, where they were evaluated for over 30 years and selected for their early bearing, high and constant productivity, as well as high oil content of the fruits and excellent chemical (oleic acid and phenol content) and organoleptic profile of the oil. This paper reports data on the horticultural performances (production, vigor, crop efficiency and oil quality) of four cultivars ('Kalat', 'Olivo di Mandanici', 'Abunara' and 'Minuta'), selected within the Sicilian's autochthonous germplasm trained as "Free Palmetta" and tested in a hedgerow planting system at three different planting densities 500, 666 and 1000 trees/ha. The cultivar 'Nocellara del Belice', 'Cerasuola, and 'Biancolilla', widely cultivated in the area where the trials were carried out, were used as references.
The outstanding performance of the cultivar 'Kalat' at planting density of 1000 trees/ha, suggests that this cultivar can be a promising choice for the super high density orchards (SHD). The other cultivars tested did not performed as 'Kalat' and seem not suitable for SHD planting system due to their high vigor. The hedgerow planting systems tested, in the first 6 years of planting, increases productivity of all cultivars compared to traditional olive orchard typical of the area were the trial was conducted. This "hedgerow" olive orchard may represent a valid solution to increase orchard productivity and to reduce harvest costs by mechanization, depending on tree high, with straddle or side by side canopy contact machines. Achieve higher yield and reducing management

costs using autochthonous, resilient cultivars, could be a new strategy to counteract climate changes. The unique organoleptic profiles of the oils obtained from the cultivars tested, could improve the offer of tasty, flavored and nutraceutical extra virgin olive oils in the international markets. Results highlight the importance of preserving and valorizing biodiversity to increase productivity and resiliency of agricultural systems, facing continuous, fast and deep socials and environmental changes.

*Response To Reviewers

Dear Editor,

Please consider our revised manuscript ID HORTI24274, entitled "Toward the valorization of olive (Olea europaea var. europaea L.) biodiversity: horticultural performance of seven Sicilian cultivars in a hedgerow planting system", by Giulia Marino, Laura Macaluso, Filipa Grilo, Francesco Paolo Marra, and Tiziano Caruso for publication in the Scientia Horticulturae Journal.

Firstly, I would like to thank you and the reviewer for the careful and constructive comments and reviews. Based on that comments, I have made changes to the manuscript that has been deeply improved.

In the following pages are my point-by-point responses to each of the comments of the reviewer:

Reviewer #2:

1- Authors should take into consideration the requirement of Scientia Horticulturae for paper submission.

The paper was formatted accordingly

2- In Material and Methods section, authors did not give indications about the orchard surface, the experimental design, the replicates number in each block, the fertilization amount during the experimentation, the pruning application, hand harvest or mechanical harvest…

All the information requested were added in the material and method at line 142 and 177-195

3- A lack of legibility of the figures

Figure legibility was improved.

4- A better description of results and a better organization.

We improved the results paragraph following the reviewer's suggestion to make it more organized and detailed

5- I ask authors why they not proceed to the measurement of oil content on dry matter basis. Indeed, the oil content on fresh matter will be affected by fruit humidity.

We thank the reviewer for this comment, effectively the expression 'oil content' that we used in the manuscript could be misleading. We substituted it with 'oil yield', which better represent what we aimed to characterize, that is the amount of oil produced per kg of fruits. We selected this method and extracted oil with a commercial mill because we wanted to have a value that could be comparable with what observed in a previous year trial (Marino et al 2017, http://dx.doi.org/10.1016/j.scienta.2017.01.046) where the oil was extracted mechanically on fresh fruits as well, with the main aim to verify productive potential of the different genotype in term of olive oil for the experimental management condition (that are typical of that specific growing area)

6-As authors have data on canopy volume, I recommend to add a new paragraph on yield efficiency (yield compared to canopy volume (Kg /m^3).

We thank the reviewer for the suggestion but we prefer to standardize production based on cm^2 of TCSA because we measured this parameter yearly and from the beginning of the experiment, while the canopy volume was measured only in 2017 when tree shape was complete, the canopy totally developed and the space in the “hedgerow” system was finally filled at least for the highest planting density.

7-I recommend to add results on fruits characteristics of studied varieties as it will help to have idea on fruit retention and then the suitability of each variety to mechanical harvesting.

Table 1 was added in the material and method to describe the main characteristic of the different genotypes’ fruits based on previous publications.

8- In general, the discussion section is well structured, follows a logical thread and uses varied bibliography to discuss its own results, however some paragraphs should be deleted as it discuss results that are not presented in the paper. For example, the paragraph which started with 'Changes in temperature' until deep changes have not relation with the paper content.

The paragraph was deleted accordingly. A second paragraph was also deleted to follow the suggestion of the reviewer (lines 435-441)

9-Authors have to classify studied cultivars following their suitability to each studied planting density.

Table 6 was added to the discussion, describing the main outstanding characteristics of the cultivars and the system they could fit better, based on this study

Thank you again for giving me the opportunity to revise and resubmit this manuscript. I hope this is now acceptable for publication in your journal.

Yours sincerely,

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Highlights

- Autochthonous cultivars trained at free palmetta in hedgerow show high yield
- ‘Kalat’ has outstanding performance and can be planted at very high densities
- Higher yields were associated with unique organoleptic profiles of the oils
- This “pedestrian” system can improve olive farms sustainability in traditional areas

Toward the valorization of olive (*Olea europaea* var. *europaea* L.) biodiversity: horticultural performance of seven Sicilian cultivars ~~trained as f~~~~Free Palmetta palmetta~~ in a hedgerow planting system

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Abstract

An intense survey of the Sicilian's olive growing areas ~~y~~ ~~fo~~for~~r~~ autochthonous germplasm, mainly represented by centennials olive trees (*Olea europaea* var. *europaea* L.) apparently older then III centuries, started at the beginning of the 1980s and resulted in the selection of more than 150 cultivars and accessions. This germplasm was propagated in a nursery, by grafting onto seedlings of *Olea europaea* L., and planted in an experimental orchard, in an olive district located in the South-west of the Island, -where they were evaluated for over 30 years~~. Four cultivars were finally~~ and selected for their early bearing, high and constant productivity, as well as high oil content of the fruits and excellent chemical (oleic acid and phenol content) and organoleptic profile of the oil. ~~We report d~~ This paper reports data on the horticultural- performances (~~tree p~~production, ~~productivity,~~ vigor, crop efficiency and oil quality) of ~~the~~ four ~~selected~~ cultivars (‘Kalat’, ‘Olivo di Mandanici’, ‘Abunara’ and ‘Minuta’), selected within the Sicilian’s autochthonous germplasm- trained as “Free

Palmetta" and tested in a hedgerow planting system at three different planting densities 500, 666 and 1000 trees/ha. The cultivar 'Nocellara del Belice', 'Cerasuola, and 'Biancolilla', widely cultivated in the area where the trials were carried out, were used as references.

The outstanding performance of the cultivar 'Kalat' at planting density of 1000 trees/ha, suggests that this cultivar can be a promising choice for the super high density orchards (SHD). The other cultivars tested did not performed as 'Kalat' and seem not suitable for SHD planting system due to their high vigor.

The hedgerow planting systems tested,~~ planted with trees trained as 'free palmetta',~~ in the first 6 years of planting, increases productivity of all cultivars compared to traditional olive orchard typical of the area were the trial was conducted. This "hedgerow"~~pedestrian"~~ olive orchard may represent a valid solution to increase ~~the level of~~ orchard productivity and to reduce~~ the~~ harvest costs by mechanization, depending on tree high, –with straddle or side by side canopy contact machines. ~~and a~~Achieve higher yield and reducing management costs using autochthonous, resilient cultivars, could be a new strategy to counteract climate changes~~-~~.

The unique organoleptic profiles of the oils obtained from the cultivars ~~genotypes~~ tested, could improve the offer of tasty, flavored and nutraceutical ~~Extra~~ extra v~~V~~irgin ~~Olive~~ olive ~~O~~oils ~~(EVOOs)~~ in the international markets.

Results highlight the importance of preserving and valorizing biodiversity to increase productivity and resiliency of agricultural systems, facing continuous, fast and deep socials and environmental changes.

Keywords: Biodiversity conservation; resilient cultivars; nutraceutical food; crop efficiency; mechanical harvesting; free palmetta.

1. Introduction

Mechanization and intensification of agricultural systems strongly increased in the last 30 years to meet the higher request for food associated with population increase. In various crops, such as apple, the intensification of planting densities has been obtained adopting dwarfing or weak rootstocks (Brooks and Olmo, 1997; Dennis and Hull, 2003), but in olive the selection of rootstocks able to reduce the size of the scion has still not been achieved (Barranco, 2010; del Río et al., 2005~~; Barranco, 2010~~).

Super high density (SHD) of plantation (~~up to~~~ 1500-2~~0~~500 tree/ha^{-1}) in olive are achieved through the use of specific cultivars, characterized by very low vigor and high flexibility of woody branches that allow full mechanization of harvesting with straddle machine. Currently, only few ~~three~~ cultivars worldwide meet these requirements and most of the SHD plantings systems are still planted with ~~one single~~only one ~~the~~ cultivar: ~~(~~‘Arbequina’~~)~~.

The ~~growing~~ wide diffusion of SHD planting system in last 20 years deeply influenced the horticultural and economical setting of olive industry. New olive producing countries, lacking of an historical olive industry and associated typical oils, quickly adopted the new SHD system, because it allows integral mechanization of harvest, ensuring their economic profitability (Fontanazza and Cappelletti, 1993; Mannino and Pannelli, 1990; ~~Fontanazza and Cappelletti, 1993;~~ Planas et al., 1997). In a SHD hedgerow planting systems~~–~~ of ~~(~~1600 trees/ha producing ~ 12 t~~)~~, harvest mechanization strongly reduces production costs respect to hand harvest: the self-propelled straddle machine can harvest one hectare in 3 hours (Tous et al 2010); i~~I~~n an intensive vase shaped planting systems ~~(~~of 300-400 trees/ha producing ~ 6 t of olives,~~)~~ the trunk shaker machine equipped with reverse umbrella harvests one hectare in 12-14 hours (Di Vaio et al 2012; Famiani et al. 2004, 2006; Pannelli et al. 1990, Tombesi et al. 1996~~; Famiani et al. 2004, 2006; Di Vaio et al 2012~~); in a traditional orchard of ~~(~~277 trees/ha producing ~ 5 t,~~)~~ hand harvest would last approximately 300 hours/ha (Sperandio et al., 2016). The situation was different for the traditional olive growing areas of the world, characterized by small groves planted with autochthonous genotypes strictly related to the territory (Marino et al., 2017). The final products of the "traditional" orchards are high quality oils generally appreciated by a niche market, but the higher managing cost and lower productivity make these systems not profitable in comparison to the i~~I~~ntensive and SHD planting systems~~ and management~~.

Most of these traditional, extensive olive orchards were abandoned in the last years because of ~~their~~ this low profitability, causing dangerous losses of genetic resources and reduction of chemical and organoleptic diversification of the oils available in the market.

The loss of biodiversity has negative ecological and social consequences, particularly in the prospective of climate changes that are challenging agricultural system productivity. Increases in the frequency and intensity of extreme climatic events will amplify agricultural production risks, particularly among smallholder farmers in developing countries (Morton, 2017). In such scenario, it is essential to increase the biodiversity in the ~~of~~ agricultural systems at the genetic and ecosystem levels, to improve their resilience thereby reducing farmers' vulnerability to climate related risks (Jackson et al. 2010; Villanueva et al. 2017).

One solution to increase economical profitability of olive systems and maintain their agro-biodiversity and environmental sustainability is ~~the use~~ to increase planting density using local genotypes characterized by reduced vigor and unique and high quality profiles of the oils.

With this knowledge, researchers carried out surveys of the autochthonous germplasm in different regions of the world (Barranco et al., 2005; Díez et al., 2011~~–~~; Muñoz-Díez, 2008; Rallo 2005~~;~~ ~~Muñoz-Díez, 2008; Díez et al., 2011~~) and of Italy (Bellomo and Godini, 2003; Camposeo et al., 2008; Farinelli and Tombesi, 2015; Godini et al., 2006;~~ Camposeo et al., 2008; Farinelli and Tombesi 2015~~) and developed trials to evaluate these autochthonous accessions at higher densities in hedgerows planting systems.

For the Sicilian region, the survey for genetic diversity started in the 1980's (Barone et al., 1993) and led to the characterization of 23 cultivars (Caruso et al., 2007). More recently, Marino et al. (2017) tested th~~e~~ose 23 cultivars for their horticultural performance in a hedgerow planting system. Only one cultivar ('Kalat') showed yield and vigor comparable to 'Arbequina', whereas other two cultivars, although more vigorous and less productive than 'Arbequina', showed early bearing, high and constant productivity in the SHD system associated to exclusive chemical composition and flavor of their olive oils~~, high oil quality~~.

The binomial "Arbequina vs SHD" is the most efficient system in economical term– but other "genotype vs growing system" combinations may have highest environmental efficiency and adapt better to different growing realities, such as different micro-climates or orographic conditions, or traditional olive growing areas where orchards are generally small (around ~~2~~1.5 ha) and rain fed. One excellent ~~good~~ example is the Sicilian cultivar 'Olivo di Mandanici', that showed very high resistance to drought (Marino et al. 2016) and diseases, would probably perform better in areas with scarce water resources.

The management protocol commonly adopted in the SHD systems has been tailed to fit the vegetative and productive requirements of the cultivar 'Arbequina' and to perform at large scale and on ~~the~~ level terrains where it is possible to harvest with straddle machines. However, each combination of environment-genotype-growing system needs its own specific management protocol (Connor et al., 2014). There is hence the need to develop correct management protocols that fit the specific needs of each genotype.

~~It is known that p~~Productivity increases with planting density (De la Rosa et al 2007; Díez et al 2016; Pastor et al 2005; Tous et al 1999~~; De la Rosa et al 2007; Pastor et al 2005; Díez et al 2016~~)~~.~~ ~~This is mainly due to~~ because of the higher light interception that affects assimilation, tree carbohydrate partitioning to fruits and, as a consequence, yield (Cherbiy-Hoffmann et al., 2012; Connor et al 2009; ~~;~~ Marino et al., 2018). However, when plantation densities are too high, shading and competition between plants may affect leaf photosynthesis, flower initiation, fruit set, fruit quality and size, as well as fruit yield and oil quality in olive (Lémole et al., 2018; Tombesi and Cartechini, 1986; Tombesi et al., 1999~~; Lémole et al., 2018~~).

Pastor et al. (2007) monitored yield at several spacing distances, from 204 trees/ha to 1,904 trees/ha, and ~~–~~demonstrated that intermediate densities produce more than the highest ones. In addition, each genotype is characterized by a specific growing habit and canopy development that may affect its yield response to planting density and shading (Tombesi and Cartechini, 1986).

In this experiment, we evaluated the vegetative and productive performance and olive oil quality traits of seven different Sicilian cultivars planted in hedgerow systems at three different spacing distances along the rows. Trees were trained at free palmetta, a very different shape with respect to the c~~C~~entral axis commonly adopted in the SHD, that allows to grow in hedgerow ~~also~~ cultivars characterized by ~~more~~ high vigor~~ous~~ and ~~having~~ thick and thus- not ~~in~~flexible fruiting branches.

Overall, the aim of the project is to develop ~~an~~ innovative but resilient planting systems for promising Sicilian olive cultivars and ~~accessions, that~~accessions that can improve competitiveness of traditional olive growing areas by: 1) ~~developing new orchard models~~ a~~reas by~~ increasing orchards' productivity ~~and~~, 2) reducing production costs ~~by~~increasing the level of harvest mechanization ~~while~~ and 3) maintaining the genetic diversification~~, for conteract climate future changes~~.

2. Materials and methods

2.1 Experimental site

The experimental orchard was a 4000 m^2 block located in a traditional growing area near Sciacca (37' 32'' N, 150 m above sea level) in South-West Sicily (Italy) was and planted in 2012 with one-year-old self-rooted olive plants, 60-80 cm tall, of 7 different Sicilian cultivars and accessions:

- 'Abunara', 'Kalat' (a candidate clone of the Sicilian minor cultivar Calatina) and 'Olivo di Mandanici', accessions selected by the Department of Agricultural and Forest Sciences of the University of Palermo based on their performance in a SHD hedgerow system (Marino et al. 2017);
- 'Biancolilla, Cerasuola and 'Nocellara del Belice', the main cultivated genotypes in Sicily, accounting for around 40% of total oil production in the region;
- 'Minuta', a minor cultivar under risk of erosion, native from an area with high altitudes. It has been recently included as 'slow food' presidium for the healthy proprieties of the oil and its exclusive flavor.

The main biometric parameters of fruits from these cultivars, previously reported by Caruso et al. 2007 and Bottari and Spina 1952, are summarized in Table 1.

/accessions

The area climate is characterized by hot and dry summers and cold winters, with yearly average precipitation of approximately 520 mm and average monthly temperature of 18.2°C (period 1965-1994 meteorological station of Sciacca, Servizio Informativo Agrometerologico Siciliano).

Soil type was sandy clay loam (60% sand, 18% silt, and 22% clay) with pH 7.7 and less than 5% active carbonates.

The tree rows were oriented North to South. Distance between the rows was 5 m while three different spacing were used between trees along the rows:

- 2 m, ~~(~~resulting in a planting density of 1000 trees ha^{-1}~~)~~;
- 3 m, ~~(~~resulting in a planting density of 666 trees ha^{-1}~~)~~;
- 4 m, ~~(~~resulting in a planting density of 500 trees ha^{-1}~~)~~.

The trees were trained to a ‘free palmetta’ shape with a single central trunk with ~~two~~three main couple of branches, oriented along the row, starting ~~by~~ at 0.7 m height above ground. The other two ~~more~~ couples of main branches were inserted at 150 and 230 cm above ground, respectively. To improve the rapid development of their canopy, trees were fasten to a trellis system, made of poles and three horizontal wires. Beside cutting few shoots oriented toward the alleys space, ~~– P~~pruning started only at the 4~~3~~th year after plantation (YAP) and was made manually, removing branches developed in wrong positions that caused shade to the selected main branches of the Palmetta. The main branches were also cut back to maintain the plant in the assigned spaces within the row. A manual topping was performed to keep plant height below 2.2 m. ~~On the first wire were connected~~ T~~t~~he irrigation driplines were connected to the first wire of the trellis system, and~~with~~ two pressurecompensating drippers per tree, with nominal flowrate of 24 l h^{-1}, distributed annually~~.~~ about 800 -1200 m^3 of water, depending on orchard age, planting density and cropping values —and -through weekly irrigation of about 80 m^3 each. ~~All the trees received identical treatment from planting until the beginning of the current experiment~~ . Starting from the 3rd YAP ~~a total amount per tree of~~ about 100 kg/ha of nitrogen, 30 kg/ha of phosphorous and 80 kg/ha of potassium were applied -with the irrigation water starting 15 days after fool bloom (mid-May) and ending 15 days before ~~until~~ harvesting (by mid-October), depending on the cultivar/accessions~~)~~.

2.2 Measurements

From the 2th to the 6th year after planting (YAP) yield per tree was ~~measured~~ manually harvested on 8~~7~~ ~~randomly selected~~ trees per cultivar selected within 4 different randomized blocks. In particular, each block was made of 4 consecutive plants within the row and the two central plants of the block were selected for measurements. All cultivars were harvested in a range of 2 to 2.5 maturity index, calculated according to Hermoso et al. (1991), in order to exclude the effect of drupe maturation variability on fruits and oil yield~~, oil accumulation~~ and overall quality.

At the end of each growing season, trunk cross-sectional area (TCSA, cm^2) was measured at 15 cm above the ground level. The TCSA and fruits yield per tree (kg) were used to calculate fruits yield efficiency (YE_{fruits} = kg of fruit/cm^2 of TCSA).

At the beginning of the 2017 season, when trees where completely shaped and at the higher density totally filled the allowed growing space -the height (h), width at first branch insertion level (w1) width at distal part of the canopy (w2) and depth (d) were measured~~,~~ on each monitored tree, and used to calculate the tree canopy volume ~~a~~ as follows:

$$V_{tree}(m^3) = \frac{(w1 \cdot d) + (w2 \cdot d) + \sqrt{(w1 \cdot d) + (w2 \cdot d)}}{3} \cdot h$$

Where w1, w2, h and d are shown in Fig 1. The V_{tree} was multiplied by the number of trees per row in one ha to obtain the total hedgerow volume per ha.

The total hedgerow volume per hectare ~~a~~ obtained was then divided by the total canopy volume that the hedgerow would occupy if the space between trees would be completely filled~~-~~ to obtain the percentage of filled hedgerow volume (V_{filled}) value per each genotype (Fig. 1):

$$V_{filled}(\%) = \frac{V_{tree} * \frac{100}{r}}{d * h}$$

Immediately postharvest the olives fruits were washed~~,~~ and crushed by a hammer mill, the obtained paste was mixed at 20-25 °C for 20 minutes and the oil was extracted by a continuous 2 phase system (Pieralisi Leopard Model 6 DMF Tec Jesi, Italy). The ~~resulting~~ oil extracted was weighted ~~weight~~ and ~~fruits yield data~~the data obtained ~~were~~were used to calculate the oil yield as the ratio between oil weigh extracted and fruits weight (%). Oil production per tree and per ha ~~and oil yield per tree.~~was then calculated. The TCSA ~~and~~ and the oil ~~yield~~ production per tree ~~(t)~~ were used to calculate oil yield efficiency (YE_{oil} = kg of oil/cm^2 of TCSA). Oil samples were stored in the dark at 11 °C until analysis.

2.3 Virgin olive oil analysis

2.3.2 Determination of quality traits

Free acidity (% of oleic acid) and peroxide value (mEq O_2 kg^{-1}) were measured according to the European Union standard methods (UE, 1989/2003 modifying the ECC 2568/91). Chlorophyll and carotenoid contents were measured using a colorimetric method with a Beckman DU 640 UV spectrophotometer at 476 nm and 670 nm, as described by Mineo et al. (2007). Total phenols quantification was carried out according to the Folin–Ciocalteau colorimetric method and expressed as mg of gallic acid/kg of oil (Montedoro et al., 1992).

2.3.3 Fatty acids determination

Fatty acids of oil samples were determined as methyl esters by gas chromatography using the method described by the International Olive Oil Council (IOOC/T20 doc N33). Quantification was carried out using a Focus GC equipped with a MEGA 10 column (50 m × 0.32 mm × 0.25 μm, Agilent Technologies, USA) and helium as carrier gas. Data were expressed as percentage of total area of the picks from each chromatogram.

2.4 Statistical analysis

Statistical analysis of the data (ANOVA) was done using R program (R Core Team, 2013). Tukey's test was used to separate means. Statistical significance was set at $p \leq 0.05$.

3.0 Results

Figure 2 shows the year to year variation in productivity (yield, t ha^{-1}) and vigor (trunk cross section area, cm^2) observed for the different cultivars independently from the planting densities.

~~Independently from the planting density,~~ 'Kalat' and 'Olivo di Mandanici' showed the highest earliness of cropping, with 3.6 and 3.3 t ha^{-1} at the 3rd YAP. 'Abunara' and 'Biancolilla' were the only cultivars not bearing any fruits before the 4th YAP.

'Kalat' in the 5th YAP had the~~The~~ highest ~~productivity~~ yield of all the experimental period~~, was recorded in the 5th YAP~~, corresponding to ~~14.5 kg tree^{-1} (~~9.5 t ha^{-1}~~), in 'Kalat'~~.

In the 6th YAP production decreased for all cultivars except for 'Biancolilla'. Particularly, 'Minuta' and 'Nocellara del Belice' showed no productivity this last year of study.

~~The TCSA was significantly affected by the cultivar but not by the planting density.~~ With the exception of 'Kalat', TCSA was relatively homogeneous among cultivars, ranging between 110 cm^2 in 'Nocellara del Belice' and 125 cm^2 in 'Minuta' at the 6th YAP. 'Kalat' had TCSA of 65 cm^2, 45% lower than the average of the other cultivars.

Table 1 and 2 show the effect of planting density and cultivar on trees' productive performance, independently from the year of observation.

The planting density negatively affected y~~Y~~ield ~~per~~ parameters on a tree basis (Table 2): ~~and fruit yield efficiency (YE$_{fruits}$)~~ yield per tree decreased from~~–~~ 21 kg tree^{-1} at 5x3 and 5x4m ~~were negatively affected by tree density (~~to 14 kg tree^{-1} at 5x2 m. Similarly, fruit yield efficiency (YE$_{fruits}$, kg of fruits per cm^2 of TCSA,) decreased from 0.09 ~~and~~ to 0.06 kg cm^{-2} ~~at 5x2 m,~~. ~~21 kg tree^{-1} and 0.09 kg cm^{-2} at 5x3 and 5x4m), while~~ T~~t~~he cumulated yield per ha increased at the highest densities ~~(~~14 t ha^{-1} at 5x2m~~–~~ and 11 t $^{-1}$ at 5x4m). ~~Cumulated oil per ha and oil yield efficiency (YE$_{oil}$) were not affected by tree spacing (Tab. 2 and 3).~~

'Kalat' was the most productive cultivar in all planting densities, with an average yield of about 7.2 t ha^{-1}, ~3 tons higher than the total average of all cultivars.~~.~~ ~~The p~~Production variability among the other cultivars was larger at the highest planting density (5x2m). In the two lowest planting densities (mainly 5x4m but also 5x3m), apart from ‘Kalat’ that constantly had the highest values, no significant differences were observed among cultivars.

~~‘Cerasuola’ had the highest fruit oil content (19%), followed by ‘Biancolilla’, ‘Kalat’, ‘Nocellara del Belice’ and ‘Abunara’ (15%). Other genotypes had 11% of fruit oil contains while ‘Minuta’ showed the lowest value (9%).~~

Considering only the 5x2m spacing and excluding ‘Kalat’, ‘Olivo di Mandanici’ had the second highest cumulated fruits yield, followed by ‘Cerasuola’; ‘Olivo di Mandanici’ and ‘Biancolilla’ showed the highest YE.~~;~~ ~~‘Cerasuola’ had the highest cumulated oil yield per ha followed by ‘Olivo di Mandanici’.~~

Cumulated oil production per ha and oil yield efficiency (YE_{oil}) were not affected by tree spacing (Table~~.~~ ~~2~~3~~ and 3~~).

‘Cerasuola’ had the highest ~~fruit~~ oil yield~~content~~ (19 %~~%~~), followed by ‘Biancolilla’, ‘Kalat’, ‘Nocellara del Belice’ and ‘Abunara’ (15 %~~%~~). Other genotypes had 11 %~~%~~ of ~~fruit~~ oil yield~~contains~~ while ‘Minuta’ showed the lowest value (9 %~~%~~) ~~.~~ In terms of oil production ‘Kalat’ was again the most productive cultivar with a yearly average production of 1.1 t ha^{-1} of oil, followed by ‘Cerasuola’ with 0.9 t ha^{-1}. Differences among cultivars were larger at the highest planting density.

~~Canopy volume was significantly different among cultivar, with lowest values in ‘Kalat’ and highest in ‘Minuta’ and ‘Cerasuola’.~~ Tree canopy volume was highest at the lowest planting density and it ~~(Fig.3A).~~was significantly different among cultivars, with lowest values in ‘Kalat’ and highest in ‘Minuta’ and ‘Cerasuola’ (Fig. 3A).

The percentage of free space filled by the canopy was almost 100% in the highest planting density (5x2 m ~~between plants along the row~~) while it strongly decreased with decreasing planting density to about 80 and 60% (5x3 ~~m~~ and 5x4 m ~~between plants~~, respectively) (Fig. 3B). No effect of the cultivar was observed on this parameter.

According to the free acidity, peroxide number, spectrophotometric investigation in the ultraviolet and fatty acid composition limits established by the International Olive Oil Council (Table 4) (COI/T.15/NC No 3/Rev. 11, July 2016), all oils studied were classified as extra-virgin olive oils (EVOOs). Chlorophyll content ranged from 4.8 to 7.6 ppm while carotenoid content ranged from 2.9 to 4.4 ppm. No differences were observed among cultivars, except for 'Cerasuola' that showed the higher level of pigment, both chlorophyll (13 ppm) and carotenoid (10 ppm), than all other cultivars studied.

Total phenols content of the oil (Table ~~3~~4) ranged from a maximum of 789 ppm in 'Minuta' to a minimum of 229 ppm in 'Abunara'. 'Kalat' had the second highest total phenol content (531 ppm) followed by 'Cerasuola' (429 ppm). In the remaining cultivars, total phenol content was between 320 and 366 ppm.

The fatty acid composition of olive oil samples from this study are shown in Table 5~~5~~. Saturated fatty acids (SFA) ranged from 13 to 17% with 'Abunara' showing the highest value of this parameter whereas 'Kalat' and 'Cerasuola' the lowest. Unsaturated fatty acid in the oils (UFA) ranged between 80 to 86% and no significant differences were observed among the cultivars studied.

'Cerasuola' had the highest UFA/SFA value with 6.9 and 'Abunara' the lowest one with 4.8. The percentage of monounsaturated fatty acids (MUFA) in the oils was around 7-13% without significant differences among cultivars. The percentage of polyunsaturated fatty acids (PUFA) was highest in 'Abunara' and 'Biancolilla' followed by 'Cerasuola' while 'Kalat' had the lowest value of this parameter. 'Kalat' was distinguished by the highest MUFA/PUFA value followed by

'Minuta' whereas 'Abunara' had the lowest value. The linoleic/oleic acid ratio ranged between 25 and 48 with no differences observed among cultivars.

4.0 Discussion

4.1 Cultivars' performance

The cultivar 'Kalat' confirmed the outstanding performance already observed in a previous, long term, experiment carried out from 2006 to 2015 in a SHD orchard located in another area of the same region (Marino et at. 2017). 'Kalat' showed early bearing and very high yield coupled with the lowest tree vigor among the cultivars tested~~-~~, just 65 cm^2 at the 6th YAP. These values resulted in outstanding values of yield efficiency (0.20 kg cm^2). Average yearly fruit yield at full production (2015, 2016 and 2017 years) was similar (about 8-9 t~~/ha~~ ha^{-1}) to what observed on 'Arbequina' at similar planting density by Díez et al. (2016). Díez et al. (2016) showed that increasing densities up to 2252 trees~~/ha~~ ha^{-1} increased productivity in 'Arbequina' and considering the similarity of the two cultivars , 'Kalat' might perform ~~similarly~~ analogously at such high density. Hence, 'Kalat' confirms to be a promising cultivar for SHD systems.

'Kalat' is still the most productive among all the cultivars studied also in term of oil ~~yield~~ production (1.3 t~~/ha~~ ha^{-1}). 'Kalat' combined high productivity with good quality oils, characterized by high total phenols content and high MUFA/PUFA ratio, differently to what observed in the previous trial (Marino et al. 2017). This difference is probably related to the sensitivity of oil chemical traits to microclimatic and management condition (Gargouri et al., 2013; Marra et al., 2016;~~,~~ Ouni et al., 2011; Vinha et al., 2005~~; Ouni et al 2011, Gargouri et al., 2013~~) and highlights the high potential of this cultivar and the importance of testing genotypes in several locations and for multiple years to precisely characterize their oil quality traits.

‘Olivo di Mandanici’ and ‘Cerasuola’ resulted highly productive cultivars. ‘Olivo di Mandanici’ confirmed its bearing earliness as previously reported, with 3.3 t ha^{-1} on the 3rd YAP and 6.9 t ha^{-1} on the 4th YAP. It ranked second as for fruit yield, with yearly average yield at full production of 4.2 t~~/ha.~~ ha^{-1} ‘Cerasuola’ was less productive than ‘Olivo di Mandanici’ in term fruit per ha (average value of 3.7 t ha^{-1}~~ha~~) but more productive in term of oil per ha (0.9 t ha^{-1}~~ha~~), thanks to the highest oil ~~contentment~~ yield (19%).~~-~~ Also in the previous experiment, this cultivar was outstanding for this parameter. ‘Cerasuola’ was also ~~showed~~ characterized by very good oil quality, with the highest pigment concentration (13 ppm of chlorophyll and 10.5 ppm of carotenoyds), very high phenol content (429 ppm) and the highest UFA/SFA ration (6.9). Also in the previous experiment ‘Cerasuola’ had the best oil quality profile particularly in term of fatty acid composition with a UFA/SFA of 10% and the phenols of 380 ppm, the second highest concentration of all 27 genotypes analyzed. The high vigor (see TCSA values) recorded in the present study for ‘Cerasuola’ and ‘Mandanaci’ also confirms the previous study’s findings.

‘Abunara’ and ‘Minuta’ showed some differences in comparison to what observed in the previous experiment. ‘Abunara’ was less productive. This may be because it was more affected than other cultivars by the adverse microclimatic condition that, during the productive season ~~year~~ 2014 and 2016, reduced olive oil production worldwide. In Sicily, olive production in 2014 was 48 % lower with respect to the previous year (http://agri.istat.it/). According to a report of the International Olive Council (IOC 2017/1), olive oil production worldwide was 20% less in 2016/2017 season compared with previous year. In Spain, the biggest producer country, production decreased by 15.8 % whereas in Italy was observed a reduction of 49% respect to the previous year. This strong yield reduction seems related to the adverse and unusual high humidity during fool bloom, associated ~~to~~ with climate change, that strongly affected pollen fertility and fruit set and also created~~ing~~ favorable development condition for the olive fruit fly (*Bactrocera oleae*) ~~(Ponti et al., 2014)~~ further impacting olive yield across the Mediterranean Basin (Olive oil Times, 2018). ~~Even if all the cultivars showed somehow such decrease of productivity in 2016, in some cultivars the yield decrease was more intense, leading to the total loss of yield, like in 'Minuta' and 'Nocellara del Belice', while other cultivars where just slightly affected. This is related to the different timing of phenological development of the various genotypes tested and it may also demonstrate a different resistance to *B. oleae* of the cultivar analyzed (Alzaghal and Mustafa 1987 probably due to differences in fruit morphology (size and weight, color, fruit epicarp hardness), surface properties and chemical components (Donia et al., 1971; Iannotta et al 2007; Neuenschwander et al., 1985: Guzmán-Delgado et al., 2017).~~

~~This unexpected response highlight the importance to preserve biodiversity to support agricultural systems that are facing continuous, fast and deep changes.~~

The minor cultivar 'Minuta', despite the low productivity, stood out from all the other genotypes for ~~a~~ its very high content of total phenol~~ content~~, reaching almost 800 ppm. Again, as for 'Kalat', these values do not correspond to the previous trial (Marino et al., 2017). Phenol content is strongly influenced by climatic and management practice, particularly irrigation~~–~~ (Caruso et al., 2014; Gargouri et al., 2013; Ouni et al., 2011; Vinha et al., 2005~~; Ouni et al., 2011, Gargouri et al., 2013~~, ~~Caruso et al., 2014~~), and this results highlighting again the importance of performing several trials to better characterize the potential of a genotype in term of oil quality at variable microclimatic conditions.

4.2 Planting density

Higher planting densities affected positively the production per ha and negatively the production per tree (Guerfel et al., 2010a; Kmicha et al., 2008; Pastor et al., 1998; Tous et al. 1999; Kmicha et al. 2008; Guerfel et al. 2010a). This was more evident in cultivars with lower vigor such 'Kalat', who increased cumulated fruits yield by 30 % (from 21 to 30 t ha^{-1} ha), and less evident in more vigorous cultivars, such as 'Minuta' or 'Cerasuola' that performed better at the lowest or medium densities. Vigorous cultivars filled the assigned space in the hedgerow earlier due to faster vegetative growth that affectand higher canopy volume. This may decrease, and may have lower their efficiency because of shading when the trees becoame adult and old (Pastor et al. 2007).

Increasing planting density improved early orchard productivity (3rd and 4th YAP), since canopies filled earlier the available space in the row (Fig. 2b2B) increasing light interception at the beginning of orchard life (-Gomez-del-Campo et al., 2017).

Density did not affect significantly TCSA, probably because the plantingcanopy densities volumes were still no so high too small to limit vegetative growth of closer trees. Canopy Canopies at the beginning of the 2017 were just starting to fill all the space available in the row, so probably increasing light competition will affect more plants growth in the next years. However, it is also possible that difference in tree density among treatments were not large enough to affect this parameter. Similarly, Tous et al. (2005) in a density experiment carried out with 'Arbequina' in 2005??? Not clear , found biggest TCSA only in the lowest density treatment (238 tree ha^{-1}) while for density higher than 555 tree ha^{-1} no difference were found. Msallem et al. (2008) found similar response with higher TCSA when tree spacing was 312 and 416 trees ha^{-1}.

4.3 Potential impact of different cultivar-management solutions

Several trials have been carried out in the last years all around the world, with the aim to find local cultivars that could fit the requirement for hedgerow~~,~~ SHD planting system (Allalout et al., 2011; Camposeo et al., 2008; De la Rosa et al., 2007; Dias et al., 2011; ~~Camposeo et al., 2008;~~ Godini et al., 2011; Larbi et al. 2011; Maia et al. 2008; Proietti et al., 2011; Tombesi et al., 2011a, b; Tous et al. 2008; ~~Allalout et al., 2011; Dias et al., 2011; Godini et al., 2011; Larbi et al. 2011; Proietti et al., 2011; Tombesi et al., 2011a, b~~). However, to our knowledge, none of these trials succeeded in discovering other autochthonous genotypes well suited for ~~hedgerow~~ this system~~s~~. Generally, the main limit that various researchers reported was the excessive vigor and the tree architecture that did not fit the requirements for such kind of plantings (Rallo et al., 2013).

This trial confirmed the outstanding performance of 'Kalat' at the highest planting density, indicating this cultivar as an actual option for SHD systems (Table 6). The binomial 'Kalat-Hedgerow plantings system' can be used to improve profitability of Sicilian olive production, achieving early and high productivity. Moreover, the use of this cultivar, having flavored and healthy olive oils, would contribute to preserve the local biodiversity of the agro systems. However, before introducing this cultivar in new areas, previous comparative field trials need to be performed, to avoid failures of adaptation due specific climatic conditions (Rallo et al., 2013).

The other Sicilian genotypes would not be suitable for hedgerow planting systems as a consequence of high vigor and specific growing habit, characterized by the presence of few, thick and strong branches that may interfere with mechanical harvesters, rather than many, thin and flexible branchlets that fit the requirements of the straddle machines (T. Caruso, personal observation).

Despite the impossibility of full harvest mechanization, the growing system tested in this experiment, with trees trained at palmetto in hedgerow with medium-high densities, allowed to significantly increase densities with respect to traditional olive system typical of this area (approximately 200 trees ha^{-1} ~~per ha~~), improving early light interception, thus orchard efficiency in the first years after plantation. Trees showed early and high productivity starting from the 4th YAP, with average production of 4 t~~/ha~~ ha^{-1} of fruits. This make this system more profitable of the traditional orchards that in these growing area produce on the average about 2 t~~/ha~~ ha^{-1} (ISTAT; FAO, 2011). ~~Furthermore, the reduced height of the trees (230 cm) and the hedgerow design of the orchard would facilitated and accelerated hand-harvesting operations, further increasing crop value (Lavee et al., 2012). Trees can be harvested without the use of ladder adopting man handled mechanical harvesters, bore on a telescopic pale. The hedgerow tree shaping, would also allow the use of self-propelled "side by side", trunk shaker or "canopy contact" harvesters.~~ Details about the suggested system for the studied cultivars are reported in Table 6,

5.0 Conclusions

The results reported here confirm the importance of preserving and evaluating local genetic resources.

The availability of the cultivar 'Kalat' for SHD system would lead several advantages to the regional and international olive industry and growers. At regional level, it would increase profitability of olive farms without renouncing to the possibility to produce a Sicilian exclusively flavored and healthy olive oil. At the international level, it would increase the resiliency of agricultural systems with higher biodiversity, introduce in the market oils with different chemical and organoleptic quality at lower price and facilitate harvesting operation, extending the harvesting period in large farms or olive growing areas.

Despite the other genotypes tested were too vigorous to meet the standard ~~on~~ for a straddle machine, ~~although~~ the growing system tested allowed a significant increase of productivity when compared to traditional olive system typically used in the studied area, improving orchard productivity, particularly in the first years after plantation.~~-~~ The reduced height of the trees (230 cm) and the hedgerow design of the orchard would accelerated hand-harvesting operations, making this system particularly profitable for table olive production, where manual harvesting is preferred to avoid mechanical damage to fruits. Furthermore, partial mechanical harvesting with alternatives machines (side by side trunk shakers; canopy contact) are under evaluation as a possible solution to facilitate harvesting operations~~ and further improve economic profitability of this system~~. This system that could be named “pedestrian~~”~~ olive system” may also represent a valuable solution for ~~all the~~ marginal areas, like moderately slope hills (up to 15%)~~-~~, where olive traditionally has been cultivated and ~~total~~ mechanical harvesting is not possible.

The wider use of alternative genotypes will increase the resilience of agricultural systems, thanks to the different drought and disease resistance of some of these cultivars.

Finally, ~~T~~the exclusive ~~high~~ top quality (flavor, nutritional and nutraceuticals value) of the oils obtained from these genotypes, would increase the offer of ~~Extra~~ extra ~~Virgin~~ virgin ~~Olive~~ olive ~~O~~oils ~~(EVOOs)~~ in the international markets.

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Figures captions

Figure 1 - Canopy measurement taken to evaluate the canopy volume per ha (h = height of the tree canopy less the free space of the trunk; w1 = width at the insertion of the first branches; w2= width at the distal part of the canopy; d = depth of the canopy, r = planting distance in the row). On the left part of the figure an example highlighting the area filled by the tree canopy and the area still not filled.

Figure 2. Fruit production per ha (A) and trunk cross section area (TCSA) (B) measured from the 3rd, to the 6th year after plantation (YAP) for the 7 selected cultivars. Vertical bars represent the standard error of the mean (n=8).

Figure 3 – Tree canopy volume (A) and percentage of free space filled by the canopy (data collected at the beginning of spring 2017) (B) for the 7 Sicilian cultivars at three different planting distances (5x2, 5x3 and 5x4m). Vertical bars represent the standard error of the mean (n=8).

Tables

Table 1. Biometric parameters of the 7 cultivars/accessions analyzed, adapted from Caruso et al. 2007 and Bottari and Spina 1952.

Cultivar	Fruit weight (g)	Longitudinal diameter (cm)	Transversal diameter (cm)	Endocarp weight (g)	Flesh/stone
Abunara	6.3	2.9	2.2	NA	NA
Biancolilla	4.5	2.3	1.8	0.57	5.2
Kalat	3.6	2.4	1.5	0.54	5.7
Cerasuola	4.3	2.2	1.7	0.56	6.8
Minuta	2.1	1.8	1.3	0.41	4.1
N.del Belice	7.4	2.5	2.0	0.82	8.1
O. di Mand.	0.41	1.5	0.65	0.41	2.9

Table 2. Cumulative fruit yield per tree and per ha (from the 2nd to the 6th YAP), yearly average fruit yield at tree maturity (average from the 4th to the 6th YAP) and fruit yield efficiency (from the 2nd to the 6th YAP) for the 7 Sicilian cultivars at three different planting distances (5x2, 5x3 and 5x4m). Significant differences among cultivars are denoted by different letters within a column; significant differences among the planting densities are denoted by different letters in the average row.

	Cum. yield per tree (Kg)			YE_{fruits} ($Kg\ cm^{-2}$)			Ave. yield per ha (t)			Cum. yield per ha (t)		
Spacing (m)	5x2	5x3	5x4	5x2	5x3	5x4	5x2	5x3	5x4	5x2	5x3	5x4
Cultivar												
Abunara	9.7cd	17.6bc	18.4b	0.03bc	0.05b	0.05b	3.2cd	3.9bc	3.1	9.7cd	11.7bc	9.2b
Biancolilla	11.1cd	16.6bc	17.2b	0.03b	0.04b	0.05b	3.7bc	3.7bc	2.9bc	11.1cd	11.1bc	8.6b
Kalat	30.7a	36.4a	42.2a	0.20a	0.26a	0.25a	8.5a	7.0a	6.1a	30.7a	24.2a	21.1a
Cerasuola	11.9c	19.7bc	20.8b	0.04bc	0.06b	0.08b	3.7bc	4.1b	3.2b	11.9c	13.1bc	10.4b
Minuta	7.5d	17.5bc	18.6b	0.02c	0.06b	0.07b	2.1d	3.3bc	2.7bc	7.5d	11.6bc	9.3b
N.del Belice	8.0cd	11.9c	11.8b	0.03bc	0.04b	0.05b	2.4cd	2.3c	1.9c	8.0cd	7.9c	5.9b
O. di Mand.	18.6b	22.5b	22.6b	0.07b	0.08b	0.09b	4.8b	4.0b	3.1bc	18.6b	15.0b	11.3b
Average	13.9b	20.3a	21.7a	0.06b	0.09a	0.09a	4.1ns	4.1	3.3	13.9a	13.5ab	10.8b

Table 3. Oil content in the fruits (average between 2015 and 2016 seasons), cumulative oil yield per ha (from the 2nd to the 6th YAP), yearly average oil yield at tree maturity (average from the 4th to the 6th YAP) and oil yield efficiency (from the 2nd to the 6th YAP) for the 7 Sicilian cultivars at three different planting distances (5x2, 5x3 and 5x4m). Significant differences among cultivars are denoted by different letters within a column; significant differences among the planting densities are denoted by different letters in the average row.

	Oil yield (%)			Cum. Oil production (t/ha)			Ave. Oil production (t/ha)			YE_{oil} ($g\ cm^{-2}$)		
Cultivar	5x2	5x3	5x4	5x2	5x3	5x4	5x2	5x3	5x4	5x2	5x3	5x4
Abunara	14.83	14.83	14.83	1.4d	1.7b	1.4c	0.5cd	0.6b	0.5c	0. 5c	0.7c	0.7c
Biancolilla	15.04	15.04	15.04	1.7cd	1.7b	1.3c	0.6c	0.6bc	0.4cd	0.5bc	0.7c	0.7c
Kalat	15.73	15.73	15.73	4.8a	3.8a	3.3a	1.3a	1.1a	1.0a	3.1a	4.1a	3.9a
Cerasuola	19.00	19.00	19.00	2.8b	3.0a	2.4b	0.9b	1.0a	0.7b	0.8b	1.3b	1.8b
Minuta	8.70	11.35	8.70	0.7e	1.3b	0.8c	0.2e	0.4bc	0.2e	0.2c	0.7c	0.6c
N.del Belice	15.00	11.35	15.00	1.2de	0.9b	0.9c	0.4de	0.3c	0.3de	0.5bc	0.5c	0.7c
O. di Mand.	11.35	11.35	11.35	2.1c	1.7b	1.3c	0.5cd	0.5c	0.3cde	0.8b	0.9bc	1.0bc
Average				2.1ns	2.0	1.6	0.6ns	0.6	0.5	0.9ns	1.3	1.4

Table 4. Chemical characteristics of oils of the cultivars studied. Data are means (n=6) recorded from 2015 and 2016 seasons and for all the three spacing treatments. Different letter within a column represent significant differences among the cultivars.

Cultivar	Free acidity (% m/m)	Peroxide (mEq of O_2 Kg^{-1})	K_{232} (nm)	K_{270} (nm)	ΔK	Chl (ppm)	Car (ppm)	Phenols (ppm)
Abunara	0.5a	7.9b	2.2 a	0.1ns	0.002ns	5.4b	3.4b	229d
Biancolilla	0.3b	6.4b	1.5 ab	0.1	-0.089	4.8b	3.0b	366cd
Kalat	0.4ab	6.1b	1.6 ab	0.1	-0.002	5.6b	4.2b	531b
Cerasuola	0.3b	5.2b	1.4 b	0.1	-0.002	13.4a	10.5a	429bc
Minuta	0.4ab	7.2b	1.7 ab	0.1	0.000	7.1b	4.0b	789a
N. del Belice	0.5a	5.8b	1.7 ab	0.1	-0.003	7.6b	4.4b	355cd
O. di Mandanici	0.5a	13.4a	1.2 b	0.1	-0.085	6.6b	2.9b	320cd
IOC 2016	<0.8	<20	<2.5	<0.22	<0.01			

Table 5. Fatty acid composition of the cultivars evaluated. Data are means (n=6) recorded from 2015 and 2016 seasons and for all the three spacing treatments. Different letter within a column represent significant differences among the cultivars

Cultivar	SFA	UFA	UFA/SFA	MUFA	PUFA	MUFA/PUFA	Linoleic/oleic
Abunara	16.8a	80.5	4.8b	66.8	13.7a	4.9c	48.3
Biancolilla	16.4ab	81.9	5.0ab	69.1	12.7a	5.5bc	42.2
Kalat	12.7b	84.0	6.7 ab	77.3	6.7c	12.1a	19.4
Cerasuola	12.7b	86.9	6.9a	76.6	10.3ab	8.2 abc	24.9
Minuta	16.0ab	80.0	5.1 ab	72.5	7.6bc	9.7ab	25.3
N. del Belice	13.8ab	83.2	6.1 ab	74.5	8.7bc	8.6 abc	27.2
O. di Mandanici	15.7ab	83.1	5.8 ab	73.8	9.3bc	9.1abc	25.7
IOC 2016	<0.8	<20	<2.5	<0.22	<0.01		

Table 6. Main characteristic and suggested growing system for the cultivar analyzed

Cultivar	Main characteristic	Suggested system
Abunara	None	Low-medium density, vase or palmetta shaped tree
Biancolilla	Sweet fresh oils	Medium density, palmetta shaped trees
Kalat	Low tree vigor, high crop efficiency	High and super high density, palmetta shaped tree
Cerasuola	Good oil yield and quality	Low-medium density, vase or palmetta shaped tree
Minuta	Very high polyphenols	Low-medium density, vase or palmetta shaped tree
N.del Belice	Fruits good for table olive	Low-medium density, vase or palmetta shaped tree
O. di Mand.	Early and good fruit production	Medium density, palmetta shaped tree

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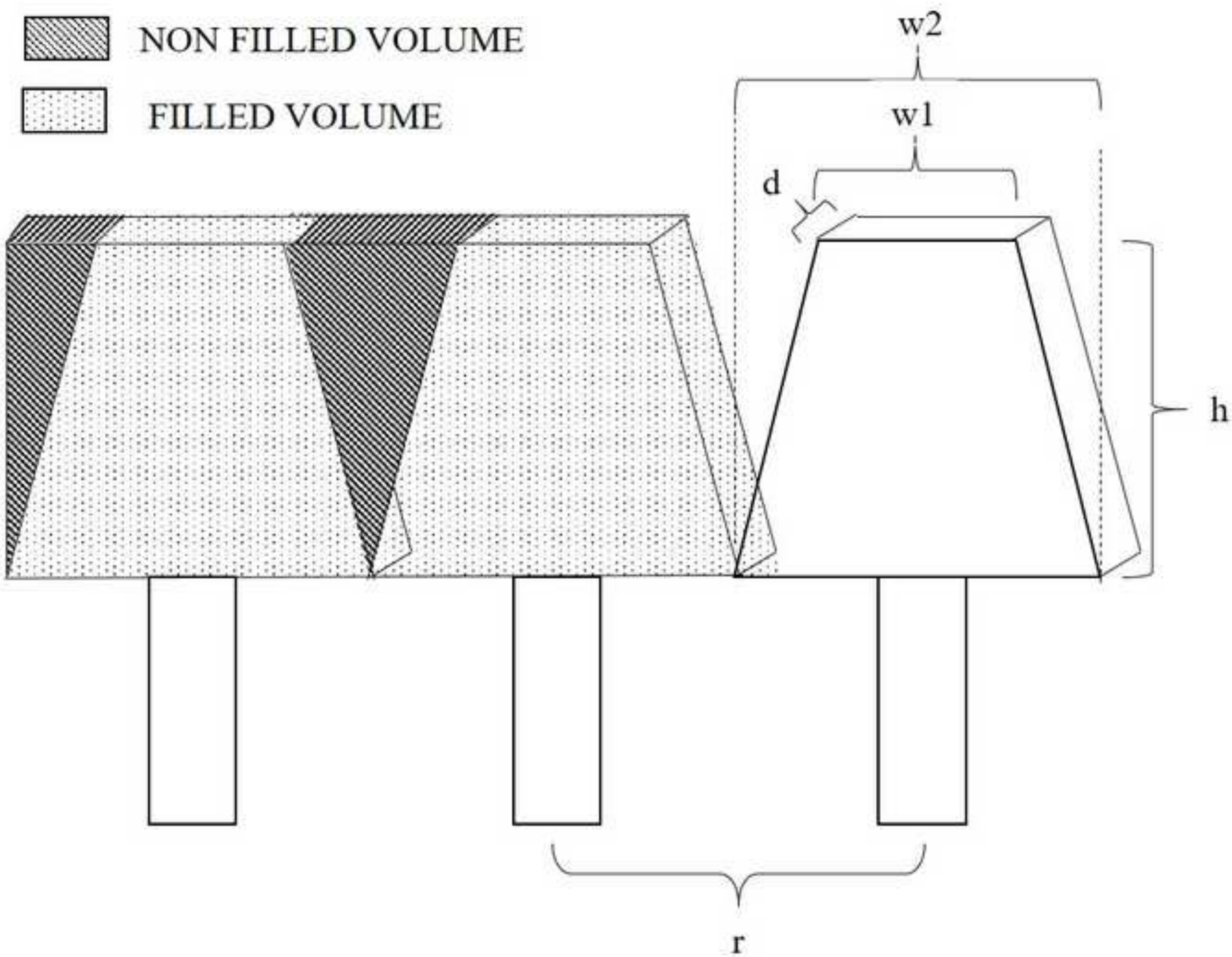

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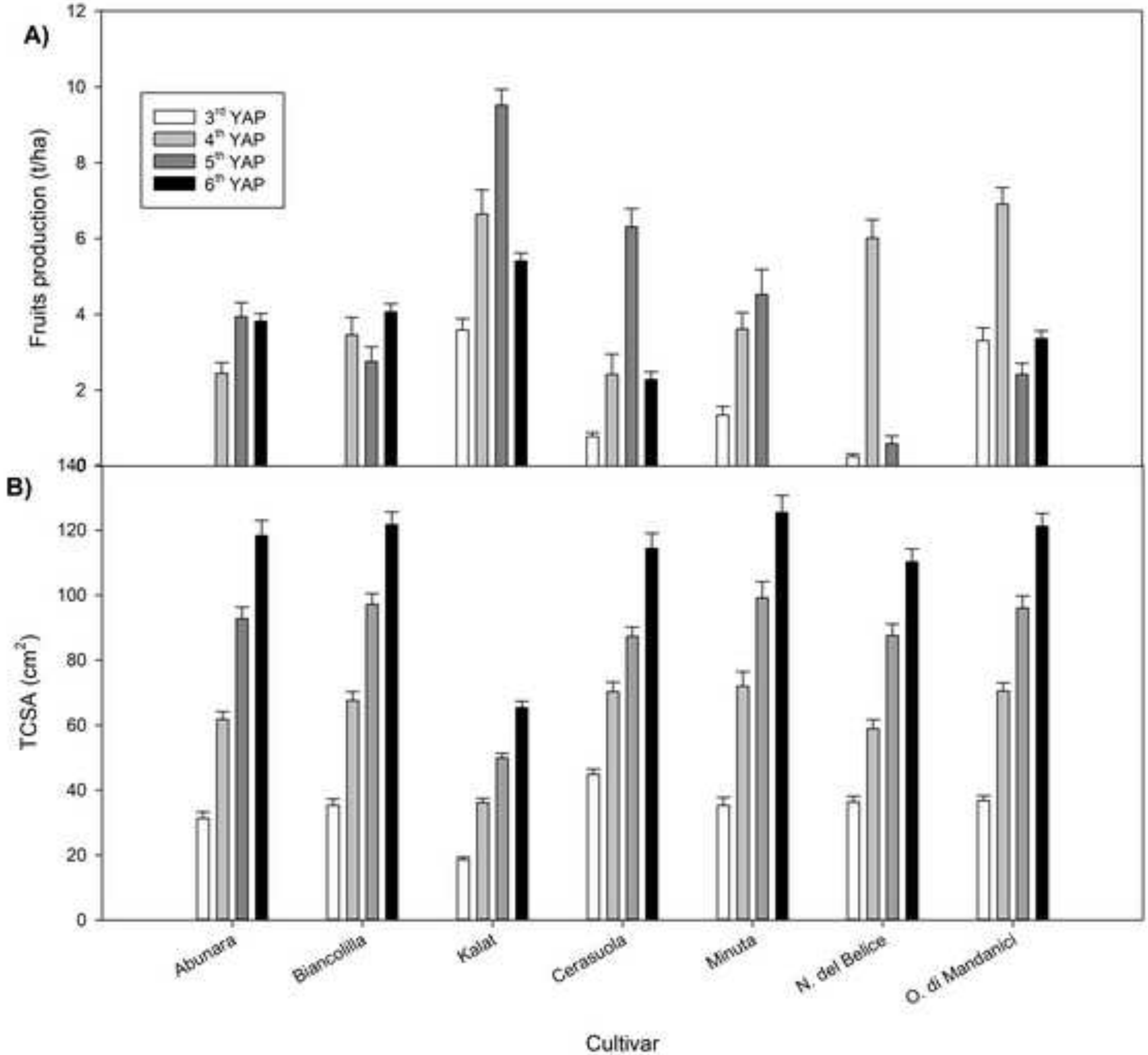

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