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Original article

Fruit production and quality evaluation of four litchi cultivars (*Litchi chinensis* Sonn.) grown in Mediterranean climate

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Summary

Introduction – **The agronomic and qualitative responses of the litchi fruit (*Litchi chinensis* Sonn.) grown in Mediterranean climate are not yet studied. In this study, yield components, physico-chemical and sensory traits of four commercial litchi cultivars were recorded over two productive seasons.** *Materials and methods* – **Fruits of the cvs Tai So, Wai Chee, Brewster and Kwai Mai were collected at commercial maturity stage and subjected to productive (yield, efficiency, number of fruits, crop load), analytical (fruit weight, transversal diameter, longitudinal diameter, moisture, total soluble solid content (TSS), titratable acidity (TA), TSS/TA ratio, seed weight, peel weight, percentage of flesh and fiber, ash, fat, protein contents, K, Na, Ca, Mg, P, Fe, Cu, Mn and Zn contents, vitamin B_1, B_2, B_3 and C contents), and sensory evaluations.** *Results and discussion* – **Even if the climatic conditions prevailing in Sicily differ from those of most litchi-growing regions, the four observed cultivars generally showed yields and fruit qualitative characteristics in line with the affirmed cultivar harvested in many tropical areas. 'Tai So' in addition to its reasonable yielding, physicochemical traits, contents of protein and vitamin, had the highest sensory appeal. 'Kwai Mai' showed interesting percentage of flesh, TSS/TA and flesh mineral composition. 'Brewster' and 'Wai Chee' revealed interesting ground colour, vit. B_2 and vit. C contents. On the other hand, 'Brewster' and 'Tai So' presented alternate bearing causing to lose a market year.** *Conclusion* – **These results suggest the possibility to produce litchi in Mediterranean climate with promising yields and an elevated standard of fruit quality.**

Keywords
Italy, litchi (*Litchi chinensis*), physico-chemical properties, fruit quality, micronutrient composition, yield component

Résumé

Production et évaluation qualitative des fruits de quatre cultivars de litchi (*Litchi chinensis* Sonn.) cultivés sous climat méditerranéen subtropical.

Significance of this study

What is already known on this subject?

- Physico-chemical and sensory analyses were used to characterize litchi fruit grown in tropical areas whereas there is a lack of information in Mediterranean climate.

What are the new findings?

- Litchi tree cultivated in Mediterranean subtropical areas is reaching promising yields and an elevated standard of fruit quality.

What is the expected impact on horticulture?

- Fresh fruit of litchi could be cultivated and commercialized in Mediterranean areas, limiting the long-distance fruit export season from tropical countries.

Introduction – **Les réponses agronomiques et qualitatives des litchis (*Litchi chinensis* Sonn.) cultivés sous climat méditerranéen n'ont pas encore été étudiées. Dans cette étude, les composantes du rendement, les caractéristiques physico-chimiques et sensorielles de quatre cultivars commerciaux de litchi ont été mesurées pendant deux saisons de production.** *Matériel et méthodes* – **Les fruits des cvs Tai So, Wai Chee, Brewster et Kwai Mai ont été collectés au stade de maturité commerciale et soumis à des évaluations quantitatives (rendement, efficacité, nombre de fruits, charge des cultures), analytiques (masse du fruit, diamètre transversal, diamètre longitudinal, humidité, teneur en matières solubles totales (TSS), acidité (TA), rapport TSS/TA, masse du noyau, masse de la coque, pourcentage de pulpe et de fibre, teneurs en cendres, en matières grasses, en protéines, en K, Na, Ca, Mg, P, Fe, Cu, Mn et Zn, en vitamines B1, B2, B3 et C), et sensorielles.** *Résultats et discussion* – **Même si les conditions climatiques qui prévalent en Sicile diffèrent de celles de la plupart des régions à litchi, les quatre cultivars observés ont généralement montré des caractéristiques quantitatives et qualitatives des fruits en ligne avec ceux cultivés et récoltés dans de nombreuses régions tropicales. 'Tai So', en plus de son rendement appréciable, de ses traits physico-chimiques, de ses teneurs protéiques et vitaminiques, a présenté les meilleures caractéristiques sensorielles. 'Kwai Mai' a montré un bon pourcentage de pulpe, un bon rapport TSS/**

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TA et une riche composition minérale de la pulpe. 'Brewster' et 'Wai Chee' ont présenté une couleur de base intéressante ainsi que de forte teneurs en vit. B2 et vit. C. Toutefois, 'Brewster' et 'Tai So' ont eu une mise à fruit alternée entraînant une perte de production d'une année. *Conclusion* **– Ces résultats suggèrent la possibilité de produire des litchis sous un climat méditerranéen avec des rendements prometteurs et un niveau élevé de qualité des fruits.**

Mots-clés
Italie, litchi (*Litchi chinensis*), propriétés physico-chimiques, qualité des fruits, composition en micronutriments, composante du rendement

Introduction

Litchi (*Litchi chinensis* Sonn.) is a tropical fruit tree native to the Guangdong and Fujian provinces of China (Wu *et al*., 2007). Litchi fruit is having high commercial value (Baoyao *et al*., 2011) and demand world over (Pandey *et al*., 2013). China is the main producing country, and now this fruit is cultivated in many parts of the world, with an annual production between 2.6 and 2.8 Mt (Chen and Huang, 2014).

Litchi was largely cultivated in tropical countries characterized by short, mild and relative dry winters and hot, wet, long summers. Litchi supplies in Europe were particularly small and it is mainly based on fruit importation from tropical countries. Indeed, from the second half of July to the end of October the export season from tropical countries ends (except from Mexico until August) and fruit is absent from the European markets. In this period the only offer comes from the Mediterranean countries (Spain, Israel and Italy) with no market saturation. As a tropical tree, in Italy litchi is cultivated only in several coastal areas of Sicily and Calabria characterized by Mediterranean climate (Padoan *et al*., 2012; Farina *et al*., in press). The climatic conditions prevailing in Sicily differ greatly from those of most litchi-growing regions: the winter is mild and wet and the summer is hot and dry. As a result, blooming is delayed to April-early May and the fruit is harvested from July until September. Currently, there is a lack of information about plant and fruit qualitative performances in Mediterranean environment.

As a non-climacteric fruit, litchi does not improve in quality after harvest (Tangtua *et al*., 2014), but has to ripen on the tree (Chen and Huang, 2001). Hence, an appropriate physiological maturity at harvest is crucial for proper marketable quality and shelf life (Reichel *et al*., 2010; Ahmed *et al*., 2012). In most litchi producing areas, fruit maturity is judged according to the fruit peel colour: fruit for immediate consumption are normally harvested at full colour (Underhill and Wong, 1990), but for long distance transport, it is harvested at 70% of the full colour (Yen *et al*., 1984) or often picked when the pericarp partly turns red (Semeerbabu *et al*., 2007; Kumar *et al*., 2012).

Litchi fruit is rich in vitamin C, niacin, riboflavin, thiamine, and β-carotene. It also contains minerals such as potassium, phosphorus, calcium, magnesium and copper. This low-calorie fruit contains no saturated fats or cholesterol, and is rich in dietary fibres and polyphenols (Kumar *et al*., 2016).

Physico-chemical analyses could be supported by sensory evaluation (Chauvin *et al*., 2010; Farina *et al*., 2015) in order to determine pericarp colour, flavor qualities, taste, odor juiciness and various important information about consumer acceptability of the ripening of fruits and evaluation of their shelf life (Sivakumar and Korsten, 2006).

The qualitative response of Litchi fruit was largely studied in tropical area whereas it was not yet analyzed in Mediterranean climate. Our aim was to study the agronomic performances and fruit quality of 4 litchi cultivars grown in the coastal areas of Sicily by physico-chemical and sensory analyses during two productive seasons.

Materials and methods

Experimental site

The trial was carried out in an experimental orchard located at Cupitur Farm in Acquedolci, province of Messina (Sicily, Italy; 38°3'N, 14°33'E; 5 m a.s.l.) during two productive seasons: 2012 was the first year for all cultivars whereas 2013 was the second in 'Kwai Mai' and 'Wai Chee' and 2014 in 'Brewster' and 'Tai So'. In fact, these last two were subjected to alternate bearing, where in this specie, is common (Mitra, 2002; Rajwana *et al*., 2010; Goren *et al*., 2001) and after a good harvest yield is reduced to even less in the following year. In this area the temperatures average 17–18 °C and the average rainfalls are close to 691 mm along 77 rainy days (Duro *et al*., 1996; Drago, 2005; Gianguzzi *et al*., 2016). Under the bioclimatic aspect, the station is referred to the upper thermos-Mediterranean lower sub-humid bioclimatic belt (Gianguzzi *et al*., 2016).

Plant material

Four litchi cultivars were studied: 'Kwai Mai', 'Wai Chee', 'Tai So' and 'Brewster'. Three uniform 11 year-old trees grafted on their own rootstock 5 × 4 m spaced and pruned to a globe shape were selected for each cultivar. Plants were subjected to organic farming routine cultural cares. The fruits were collected at commercial harvest from the last week of August to the first decade of September (Table 1), in coincidence with the ends of the export season from tropical countries, using skin colour as maturity index (Semeerbabu *et al*., 2007; Kumar *et al*., 2012).

Yield components

Weighing and counting the total number of fruits per

Table 1. Origin, harvest date, season, vigour, skin colour and flesh colour of the fruit of four litchi cultivars cultivated in a Mediterranean environment.

Cultivars	Countries of origin	Harvest dates (year I)	Harvest dates (year II)	Fruit maturity	Tree vigour	Fruit skin colour	Fruit flesh colour
'Brewster'	China	20th August	23rd August	Mid	Vigorous	Deep red	Waxy white
'Kwai Mai'	China	15th August	12th August	Mid	Medium	Light red	White
'Tai So'	Thailand	14th July	13th July	Early	Vigorous	Bright red	Milky white
'Wai Chee'	Thailand	15th September	17th September	Late	Dwarf	Dull red	Milky white

tree was measured to express the yield per tree. After fruit harvest, trunk circumference was measured at ~15 cm above the soil. Yield efficiency and crop load were expressed as kilogram or number of fruits per trunk cross-sectional area (TCSA) or leaf area.

Physico-chemical analyses

A sample of 10 fruits per tree per cultivar were collected and submitted to analytical and sensory evaluations immediately after harvest. In particular, fruit weight (FW), longitudinal diameter (LD), transversal diameter (TD), seed weight (SW), peel weight (PW), total soluble solid content (TSS) titratable acidity (TA) and total dietary fiber (TDF) were analyzed. FW, SW, PW (g) were determined by a digital scale (Gibertini EU–C 2002 RS, Novate Milanese, Italy); LD and TD (mm) by digital caliper TR53307 (Turoni, Forlì, Italy); TSS (as °Brix) by digital refractometer Atago Palette PR–32 (Atago Co., Ltd., Tokyo, Japan); TA (as percent of citric acid) using a CrisonS compact titrator (Crison Instruments, SA, Barcelona, Spain). Moreover, TSS/TA ratio and flesh percentage (FP) were calculated.

Each fruit was photographed with a digital camera and digital images were used to determine intensity of peel colour. Specifically, the software FAS (fruit analysis system) used an algorithm that converts images from RGB to CIE (Commission Internationale de l'Eclairage) L*a*b* format, extracts the fruit from the image (removing the image background), and quantifies colour characteristics as the weighed distance of each pixel in the image from a reference sample (best coloured area interactively chosen from a well-coloured fruit). The output was a peel colour index (CI) ranging from 0 to 1 (identical to reference sample) (Talluto *et al*., 2007).

Chemical composition

Ash content was determined through the procedure described in AOAC (AOAC, 1985a, 1985b, 1985c, 1985d, 1985e) while the Kjeldahl method was used for protein determination. In particular, a sample rate was subjected to acid-catalyzed mineralization to turn the organic nitrogen into ammoniacal nitrogen and subsequently was distilled in an alkaline pH. The ammonia formed during this distillation was collected in a boric acid solution and determined through titrimetric dosage. The value of ammoniacal nitrogen was multiplied by 6.25 (Palazzolo *et al*., 2012).

The fat content (FAT) was obtained through acid hydrolysis with a 1:4 HCl solution on the sample followed by filtration and dehydration in a heater (70 °C). After solvent evaporation, the extraction in Soxhlet with petroleum ether was determined through a gravimetric method of residual fat.

The carbohydrate content (TSG), either free or present in polysaccharides, was obtained with the anthrone method reported in Loews (1952). Carbohydrates were first hydrolyzed into simple sugars using dilute hydrochloric acid. In hot acidic medium, glucose is dehydrated to hydroxymethyl furfural that with anthrone forms a green-coloured product with an absorption maximum at 630 nm (Palazzolo *et al*., 2012).

The contents of K, Na, Ca, Mg, Fe, Cu, Mn and Zn were determined using atomic absorption spectroscopy following wet mineralization while P was determined using a colorimetric method (Morand and Gullo, 1970).

The riboflavin (Vit. B_2) was extracted in an autoclave with a solution of diluted H_2SO_4 and later, after enzymatic treatment, was determined through HPLC (for the fluorescent spectra) (AOAC, 1985b).

The Niacin (Vit. B_3) was extracted from the sample in an acidic solution at 12–18 °C for 30 min and measured through a microbiological method. The titrator strain was *Lactobacillus plantarum* ATCC8014. The test was carried out in a liquid culture medium with all the indispensable factors for the growth of *L. plantarum* present with the exclusion of the examined vitamin. The presence of niacin in the sample caused a proportional increase of growth of *L. plantarum* after 24 h of incubation at 37.8 °C. The growth was evaluated using a turbidimeter and was then compared with the values of a standard curve prepared in parallel to the test (Palazzolo *et al*., 2012).

The thiamine content (Vit. B_1) was obtained through extraction in 0.1 N HCl and oxidation by thiochromium and analysis in HPLC using fluorometric detection (AOAC, 1985c, 1985d, 1985e).

The ascorbic acid (Vit. C) was determined according to procedures previously described by Barros *et al.* (2007). For this determination the dried methanolic extract (100 mg) was extracted with 10 mL of 1% metaphosphoric acid for 45 min at room temperature and filtered through Whatman No. 4 filter paper. The filtrate (1 mL) was mixed with 9 mL of 2.6–dichlorophenolindophenol and the absorbance was measured within 30 min at 515 nm against a blank. Ascorbic acid was calculated on the basis of the calibration curve of authentic L-ascorbic acid (0.02–0.12 mg mL^{-1}):

$$Y = 3.4127\ X - 0.0072,\ R^2 = 0.9905$$

and the results were expressed as mg ascorbic acid g^{-1} extract (Palazzolo *et al*., 2012).

Sensory analysis

For the sensory characterization, a subsample of 5 fruits per tree per cultivar was submitted to the sensory profile analysis immediately after picking according to the UNI 10957 (UNI 10957, 2003) by a trained panel consisting of ten judges (5 females and 5 males, 22–35 years old). All panelists were trained and developed a wide expertise in sensory evaluation of fruits (Farina *et al*., 2010, 2015, 2016; Liguori *et al*., 2014). The judges, in preliminary sessions, using both commercial and experimental litchi samples, generated 15 sensory descriptors: flesh colour (FC); consistency (C), fruity odour (FO), exotic fruits odour (EXO), off-odour (OFO), sweet (S), acid (A), juicy (J), astringent (AS), pungent (PU), fruits flavour (FRF), exotic fruits flavor (EXF), flavour alcohol (ALF), off-flavour (OFF) and overall evaluation (OVE). The evaluations were carried out from 10.00 to 12.00 *a.m.* in individual booths with controlled illumination and temperature. In each session, judges evaluated the samples in triplicate. The sample order for each panelist was randomized and water was provided for rinsing between litchi samples. The judges evaluated samples, using a hedonic scale, assigning to each descriptor a score from 1 to 9 according to Dong *et al.* (2004): 9- Excellent (fully characteristic litchi, white and translucency; just peeled); 7– Very good (pleasantly mild litchi, white and translucency); 5– Good (blandly faint litchi, white but less translucency; limit of marketability); 3– Fair (faint off-odor, white-brown, no translucency, limit of unacceptability); and 1– Poor (distinct off-odor, brown, no translucency).

Assessments were conducted at the laboratory of sensory analysis at University of Catania, built to UNI EN ISO 8589

Table 2. Yield components (fruit mass per tree, number of fruits per tree, yield efficiency and crop load) of the 4 observed cultivars during two cropping seasons. Data are mean values ± SD (n = 10). The values marked with different letters in the same column indicate significant differences (P < 0.05). TCSA: trunk cross-sectional area.

Cultivars	Yield (kg tree^{-1})		Number of fruits tree^{-1}		Yield efficiency (kg cm^{-2} TCSA)		Crop load (fruit no. cm^{-2} TCSA)	
				Year I				
'Brewster'	28.25 ± 4.12	b	1,182.5 ± 44.34	b	0.22 ± 0.03	b	9.86 ± 0.77	b
'Kwai Mai'	29.30 ± 3.85	b	1,493.4 ± 56.86	a	0.30 ± 0.02	ab	15.68 ± 0.44	a
'Tai So'	38.50 ± 2.89	a	1,227.7 ± 78.28	b	0.30 ± 0.05	ab	10.01 ± 0.32	b
'Wai Chee'	16.70 ± 3.59	c	977.2 ± 36.75	c	0.34 ± 0.02	a	17.64±0.83	a
				Year II				
'Brewster'	32.24 ± 5.50	b	1,349.5 ± 55.06	b	0.25 ± 0.01	b	10.59 ± 0.56	b
'Kwai Mai'	33.56 ± 4.72	b	1,710.5 ± 29.35	a	0.34 ± 0.02	a	17.53 ± 0.46	a
'Tai So'	44.51 ± 3.55	a	1,419.3 ± 70.20	ab	0.35 ± 0.03	a	11.14 ± 0.97	b
'Wai Chee'	17.88 ± 2.88	c	1,046.2 ± 80.57	c	0.36 ± 0.06	a	21.02 ± 1.10	a

Table 4. Physico-chemical traits of the fruit of the 4 litchi cultivars harvested for two cropping seasons. Total soluble solids content (TSS); Titratable Acidity (TA); and TSS/TA ratio. Data are mean values ± SD (n = 10). The values marked with different letters in the same column indicate significant differences (P < 0.05).

Cultivars	TSS (°Brix)	TA (g 100 g^{-1})	TSS/TA
		Year I	
'Brewster'	17.95 ± 0.03 b	0.146 ± 0.001 b	122.50 ± 3.06 ab
'Kwai Mai'	19.74 ± 0.21 a	0.153 ± 0.001 b	126.20 ± 4.02 a
'Tai So'	19.64 ± 0.26 a	0.186 ± 0.010 a	105.60 ± 4.82 b
'Wai Chee'	17.50 ± 0.28 b	0.153 ± 0.001 b	114.30 ± 4.20 ab
		Year II	
'Brewster'	18.11 ± 0.04 b	0.131 ± 0.002 ns	138.24 ± 2.51 b
'Kwai Mai'	20.04 ± 0.12 a	0.135 ± 0.009 ns	148.44 ± 3.21 a
'Tai So'	19.94 ± 0.18 a	0.134 ± 0.010 ns	148.80 ± 3.51 a
'Wai Chee'	18.31 ± 0.22 b	0.142 ± 0.005 ns	128.94 ± 3.92 b

Table 5. Fruit flesh composition (in g 100 g^{-1}) of the 4 litchi cultivars harvested for two cropping seasons: Moisture (MST); Protein (PRO); Fats (FAT), Total dietary fibers (TDF); Total sugars (TSG); and Ash (ASH). Data are mean values ± SD (n = 10). The values marked with different letters in the same column indicate significantly differences (P < 0.05), ns = not significant.

Cultivars	MST	PRO	FAT	TDF	TSG	ASH
			Year I			
'Brewster'	86.07 ± 0.09 a	0.806 ± 0.02 b	0.113 ± 0.01 ns	1.176 ± 0.01 ns	11.55 ± 0.05 b	0.280 ± 0.01 b
'Kwai Mai'	84.83 ± 0.30 b	0.723 ± 0.01 b	0.086 ± 0.01 ns	1.156 ± 0.03 ns	12.83 ± 0.20 a	0.257 ± 0.01 b
'Tai So'	83.87 ± 0.33 b	0.963 ± 0.05 a	0.040 ± 0.03 ns	1.233 ± 0.05 ns	12.57 ± 0.33 a	0.426 ± 0.03 a
'Wai Chee'	85.89 ± 0.08 a	0.770 ± 0.01 b	0.103 ± 0.00 ns	1.180 ± 0.02 ns	11.07 ± 0.05 b	0.287 ± 0.02 b
			Year II			
'Brewster'	85.05 ± 0.06 ns	0.815 ± 0.03 b	0.096 ± 0.02 ns	1.129 ± 0.02 ns	11.12 ± 0.03 b	0.284 ± 0.02 b
'Kwai Mai'	83.33 ± 0.19 ns	0.744 ± 0.02 c	0.076 ± 0.02 ns	1.141 ± 0.02 ns	12.23 ± 0.20 a	0.243 ± 0.02 b
'Tai So'	82.17 ± 0.32 ns	0.898 ± 0.01 a	0.070 ± 0.01 ns	1.223 ± 0.04 ns	12.37 ± 0.13 a	0.434 ± 0.01 a
'Wai Chee'	84.19 ± 0.09 ns	0.760 ± 0.02 c	0.101 ± 0.03 ns	1.113 ± 0.01 ns	11.06 ± 0.05 b	0.272 ± 0.03 b

Table 3. Pomological traits of the 4 litchi cultivars measured over two cropping seasons: Fruit weight (FW); Fruit longitudinal diameter (LD); Fruit transversal diameter (TD); Seed weight (SW); Seed longitudinal diameter (SLD); Seed transversal diameter (STD); Peel weight (PW); Color index (CI); and Flesh percentage (FP). Data are mean values ± SD (n = 10). The values marked with different letters in the same column indicate significant differences (P < 0.05).

Cultivars	FW (g)	LD (mm)	TD (mm)	SW (g)	SLD (mm)	STD (mm)	PW (g)	CI	FP (%)
					Year I				
'Brewster'	23.89 ± 0.91 b	39.50 ± 0.07 a	35.40 ± 0.05 a	1.92 ± 0.55 b	19.50 ± 0.12 b	11.50 ± 0.09 b	5.63 ± 0.30 a	0.952 ± 0.01 b	68.39
'Kwai Mai'	19.62 ± 0.73 c	34.20 ± 0.04 b	33.30 ± 0.05 b	0.83 ± 0.19 c	15.50 ± 0.08 c	8.10 ± 0.06 c	3.12 ± 0.10 c	0.929 ± 0.02 c	79.86
'Tai So'	31.36 ± 0.72 a	38.70 ± 0.08 a	30.50 ± 0.05 c	2.74 ± 0.21 a	22.00 ± 0.07 a	13.70 ± 0.04 a	4.69 ± 0.10 b	0.955 ± 0.01 b	76.30
'Wai Chee'	17.09 ± 0.63 c	31.30 ± 0.07 c	31.30 ± 0.07 c	1.36 ± 0.15 bc	17.10 ± 0.05 c	10.30 ± 0.03 b	3.54 ± 0.10 c	0.994 ± 0.02 a	71.32
					Year II				
'Brewster'	28.89 ± 0.71 b	41.60 ± 0.10 a	36.30 ± 0.07 a	2.05 ± 0.32 b	22.32 ± 0.21 b	12.31 ± 0.05 b	6.23 ± 0.40 a	0.959 ± 0.01 b	76.41
'Kwai Mai'	21.16 ± 0.73 c	36.10 ± 0.09 b	34.21 ± 0.06 b	0.95 ± 0.18 c	18.62 ± 0.10 c	10.08 ± 0.10 c	4.32 ± 0.30 c	0.945 ± 0.01 c	85.02
'Tai So'	35.42 ± 0.69 a	40.02 ± 0.06 a	32.49 ± 0.06 c	2.55 ± 0.25 a	24.54 ± 0.12 a	14.90 ± 0.08 a	5.25 ± 0.20 b	0.960 ± 0.01 b	81.56
'Wai Chee'	20.05 ± 0.51 c	33.40 ± 0.10 c	32.70 ± 0.07 c	1.45 ± 0.13 bc	19.20 ± 0.09 c	12.41 ± 0.09 b	4.44 ± 0.20 c	0.989 ± 0.01 a	80.30

(2014) with a specific software for sensory data acquisition (FIZZ, Software Solutions for Sensory Analysis and Consumer Tests, Biosystèmes, Couternon, France).

Data analysis

The chemical and sensory data were tested for differences between the cultivars using the one-way analysis of variance (ANOVA; general linear model). The differences between cultivars were tested with Tukey's high significance difference (HSD) test at the P < 0.05 significant level.

Results and discussion

Yield components

All the cultivars showed a similar behavior during the two seasons (Table 2). 'Tai So' was the more productive tree reaching more than 40 kg tree^{-1} during the second year. It was followed by 'Brewster' with 35 kg tree^{-1} and by 'Tai So' and 'Wai Chee' that reached 30 kg tree^{-1} in the second year. Our results are comparable with the varieties grown in tropical environment (30–40 kg tree^{-1}) (Stern *et al.*, 1993). On the other hand, 'Brewster' and 'Tai So' presented alternate bearing causing to lose a market year. Yield efficiency were quite similar for all the cultivars except for 'Brewster' whereas the highest crop load was observed in 'Kwai Mai' and 'Wai Chee'.

Physico-chemical analyses

The examined litchi cultivars showed a great variability in pomological aspects and they differ significantly in several physicochemical characteristics (Tables 3–5).

'Tai So' showed, during the two seasons, the greater fruit weight (FW) followed by 'Brewster', whereas the smallest FW were observed for 'Kwai Mai' and 'Wai Chee'. Diameter values confirmed the classification of fruit on the basis of FW. Weight and diameter define fruit size and are important commercial characteristics for the market needs. In this case, for litchi fruit, the best size is around 22–30 g due to packaging and logistics practices (Chang and Lin, 2006). Following this indication, 'Brewster' just coincides in this range, nevertheless 'Tai So' was bigger whereas only 'Wai Chee' and 'Kwai Mai' were slightly smaller. Another important feature is the flesh percentage (FP) that indicates the edible part of fruit. As expected, the highest values of seed weight (SW) and peel weight (PW) were observed in the biggest fruits. The highest FP was observed in 'Kwai Mai' and 'Tai So'. Both seed longitudinal and transversal diameters (SLD and STD) confirmed the values of SW. Fruit colour is the first characteristic of quality perceived by the consumers who generally prefer a well and intense coloured fruit ranging from pink to red (Ruenroengklin *et al.*, 2009) without browning (Sun *et al.*, 2009). In this case, 'Wai Chee', exhibited the highest values of colour index (CI) followed by 'Tai So' and 'Brewster' whereas 'Kwai Mai' has the lowest value. Our results showed, in every case, a level of CI very close to the reference sample (Talluto *et al.*, 2007) indicating a well and intensely coloured fruit.

The total soluble solid content (TSS) is responsible for fruit taste, affecting fruit sweetness and consequently consumer appreciation. TSS was greater in 'Kwai Mai' and 'Tai So', followed by 'Brewster' and 'Wai Chee' during the two observation years. Similar TSS value (17–20 °Brix) has been reported in litchi from China, Taiwan, Hawaii, and Australia (Chang and Lin, 2006; Hajare *et al.*, 2010; Fay and Halfpapp, 1993). As for TA, 'Tai So' during the first year showed the

Table 6. Fruit flesh mineral composition (in mg 100 g^{-1}) of the 4 litchi cultivars during two seasons. Potassium (K); Sodium (Na); Calcium (Ca); Magnesium (Mg); Phosphorus (P); Iron (Fe); Copper (Cu); Manganese (Mn); Zinc (Zn). Data are mean values ± SD (n = 10). The values marked with different letters in the same column indicate significant differences (P < 0.05); ns = not significant.

Cultivars	K	Na	Ca	Mg	P	Fe	Cu	Mn	Zn
					Year I				
'Brewster'	18.99 ± 0.22 c	7.32 ± 0.19 b	11.46 ± 0.13 b	1.31 ± 0.03 b	24.91 ± 0.04 b	0.12 ± 0.01 d	0.053 ± 0.000 d	0.016 ± 0.000 ns	0.62 ± 0.07 c
'Kwai Mai'	24.93 ± 2.32 b	7.68 ± 0.13 b	12.13 ± 0.08 b	1.71 ± 0.01 a	25.63 ± 0.09 b	0.18 ± 0.00 b	0.826 ± 0.000 b	0.020 ± 0.000 ns	1.40 ± 0.01 b
'Tai So'	38.72 ± 0.17 a	10.18 ± 0.43 a	15.88 ± 0.30 a	1.81 ± 0.05 a	44.71 ± 0.92 a	0.29 ± 0.01 a	0.860 ± 0.000 a	0.036 ± 0.010 ns	1.85 ± 0.04 a
'Wai Chee'	19.09 ± 0.07 c	7.35 ± 0.06 b	11.47 ± 0.11 b	1.45 ± 0.05 b	23.57 ± 0.04 b	0.16 ± 0.01 c	0.776 ± 0.010 c	0.018 ± 0.000 ns	0.78 ± 0.01 c
					Year II				
'Brewster'	19.36 ± 0.09 b	7.11 ± 0.29 b	12.15 ± 0.23 b	1.42 ± 0.04 ns	23.11 ± 0.06 b	0.14 ± 0.02 c	0.877 ± 0.010 b	0.018 ± 0.010 ns	0.59 ± 0.09 c
'Kwai Mai'	20.31 ± 1.24 b	7.18 ± 0.22 b	11.98 ± 0.16 b	1.45 ± 0.01 ns	23.33 ± 0.19 b	0.18 ± 0.00 b	0.814 ± 0.020 b	0.022 ± 0.000 ns	1.27 ± 0.02 b
'Tai So'	35.60 ± 1.06 a	9.42 ± 0.43 a	14.74 ± 0.46 a	1.46 ± 0.06 ns	39.65 ± 0.12 a	0.25 ± 0.01 a	0.954 ± 0.000 a	0.029 ± 0.010 ns	1.92 ± 0.05 a
'Wai Chee'	20.10 ± 0.27 c	5.34 ± 0.15 c	11.65 ± 0.25 b	1.39 ± 0.05 ns	13.17 ± 0.24 c	0.15 ± 0.02 c	0.634 ± 0.010 c	0.021 ± 0.000 ns	0.66 ± 0.03 c

highest value followed by the other cultivars whereas all the four cultivars did not differ significantly during the second year. Our fruits were less acid in respect to other studies (Hajare *et al*., 2010). The highest values of TSS/TA ratio were observed in 'Kwai Mai' and 'Brewster' followed by 'Wai Chee' and 'Tai So'.

Chemical composition

The content of flesh composition is presented in Table 5. All varieties showed significant moisture content, on average 85.17 g 100 g^{-1} during the first year and 83.68 g 100 g^{-1} during the second year. 'Brewster' and 'Wai Chee' presented the highest MST values followed by 'Kway Mai' and 'Tai So' only during the first year. Level of moisture in a fruit is an important factor as it could affect its texture and overall acceptability (Hajare *et al*., 2010). Similar values (79–82 g 100 g^{-1}) were reported in tropical areas (Hawaii) (Fay and Halfpapp, 1993).

'Tai So' showed the highest PRO content followed by the other three cultivars, and the values ranged from 0.963 to 0.723 g 100 g^{-1}. During the first year and from 0.744 to 0.898 g 100 g^{-1} during the second year. In both years the values were greater in respect to the fruits grown in tropical areas (0.0253 g 100 g^{-1}) (Zhang *et al*., 2005).

Fat (FAT) and fiber (TDF) values in all varieties did not show significant differences during both years. Our fruits reached higher TDF contents than the fruits grown in South Florida (Mahattanatawee *et al*., 2006).

The carbohydrate content (TSG) ranged from 11.07 to 12.83 g 100 g^{-1} in agreement with available report (USDA, 2007). 'Kwai Mai' and 'Tai So' showed the highest values followed by 'Brewster' and 'Wai Chee' over the two years.

'Tai So' regularly showed the greatest ASH content followed by 'Wai Chee', 'Brewster' and 'Kwai Mai'.

In the flesh mineral composition (Table 6) phosphorus (P) was in both years the predominant mineral element of the litchi fruit. P content was greater in 'Tai So' than in the other three cultivars. Potassium (K) was the second most present mineral element in the observed litchi fruit. K was greater in 'Tai So' followed by 'Kwai Mai', 'Wai Chee' and 'Brewster'.

As for the other mineral elements 'Tai So' showed the highest values, followed by 'Kwai Mai', 'Wai Chee' and 'Brewster'. These data are similar to those reported in other recent studies and in some cases expressed higher mineral contents (Baoyao *et al*., 2011; Cabral *et al*., 2014).

The vitamin contents are listed in Table 7. The measured Vit. C content of litchi fruit was higher in 'Tai So' than in 'Brewster' and 'Wai Chee' and, finally in 'Kwai Mai'. In every case, these values are greater in respect to those measured in litchi fruit grown in Hawaiian or Brazilian areas (range of 21–36 mg 100 g^{-1}) (Fay and Halfpapp, 1993; Cabral *et al*., 2014) and to the value (36 mg 100 g^{-1}) reported by the USDA National Nutrient Database. Today, nutraceutical traits are considered by consumers as an added value. Our data indicate an interesting vitamin C content for all the observed cultivars, expecting then a good market appreciation.

Thiamine (Vit. B_1) content was higher in 'Tai So' and 'Kwai Mai', followed by 'Wai Chee' and finally by 'Brewster'. Riboflavin (Vit. B_2) content was higher in 'Tai So' and 'Wai Chee' followed by 'Brewster' and 'Kwai Mai'. Niacin (Vit. B_3) content was higher in 'Tai So' and 'Kwai Mai', followed by 'Brewster' and 'Wai Chee'. These results are in line with other studies conducted on litchi fruit in tropical areas and, in the case of Vit. B_1, show very high contents (Menzel, 2002).

Table 7. Vitaminic composition (in mg 100 g^{-1}) of the fruits of the 4 litchi cultivars during two cropping seasons: Thiamin (Vit. B_1); Riboflavin (Vit. B_2); Niacin (Vit. B_3); Ascorbic acid (Vit. C). Data are mean values ± SD (n = 10). The values marked with different letters in the same column indicate significant differences (P < 0.05).

Cultivars	Vit. B_1	Vit. B_2	Vit. B_3	Vit. C
		Year I		
'Brewster'	23.00 ± 0.02 d	0.053 ± 0.010 b	0.513 ± 1.000 b	57.00 ± 1.73 b
'Kwai Mai'	28.00 ± 0.01 b	0.046 ± 0.000 b	0.716 ± 0.580 a	41.33 ± 2.03 c
'Tai So'	31.00 ± 0.05 a	0.090 ± 0.010 a	0.743 ± 0.580 a	77.66 ± 1.45 a
'Wai Chee'	25.66 ± 0.03 c	0.080 ± 0.010 a	0.463 ± 1.200 b	54.66 ± 1.45 b
		Year II		
'Brewster'	21.80 ± 0.01 c	0.047 ± 0.010 c	0.456 ± 0.820 b	51.17 ± 1.01 b
'Kwai Mai'	26.60 ± 0.03 b	0.041 ± 0.030 c	0.716 ± 0.380 a	42.61 ± 1.03 c
'Tai So'	34.57 ± 0.02 a	0.084 ± 0.010 a	0.820 ± 0.210 a	74.61 ± 1.13 a
'Wai Chee'	26.56 ± 0.01 b	0.068 ± 0.010 b	0.445 ± 0.100 b	53.22 ± 0.95 b

Sensory analyses

Sensory results from the trained panel (Figure 1) proved that the four cultivars grown in a Mediterranean environment had good characteristics for fresh consumption because of the high intensity of several key flavour attributes.

No significant difference between cultivars was found for any descriptor except for the following ones: flesh colour (FC), fruity odour (FO), exotic fruits odour (EXO), sweetness (S), off-flavour (OFF) and overall evaluation (OVE). Between the four tested cultivars, 'Wai Chee' had the highest intensity for descriptors FC and OFF, while 'Tai So' had the highest intensity for FO, EXO and OVE and the lowest for OFF. 'Kwai Mai' produced the sweetest fruit. Generally, the descriptors with negative connotation reached very low values.

The sensory results on FO and S, compared to those obtained with the instrumental analysis, showed a perfect correspondence of the two types of determination.

Conclusion

The obtained results suggest it is possible to cultivate litchis in the Mediterranean climate, with promising yields and an elevated standard of fruit quality. Even if the climatic conditions prevailing in Sicily differ from those of most litchi-growing regions, the four observed cultivars generally showed yields and fruit qualitative characteristics in line with the affirmed cultivar harvested in many tropical areas.

As a result of Sicily's mild wet winters followed by hot dry summers, litchi's bloom is delayed to March to early April in respect to tropical areas and the fruit is harvested from July until September. 'Brewster' and 'Tai So' were confirmed to bear alternately, thus causing growers to lose a market year; whereas 'Kwai Mai' and 'Wai Chee' produced consecutively during both two observation years.

All the observed cultivars grown in Sicily generated yield components, TSS, TSG and MST similar to the values obtained in tropical areas such as in China, Taiwan, Hawaii, Florida, Mauritius or Australia. Moreover, our fruits presented a low acidity (TA) and interesting contents of fibers, mineral elements, Vit. C and Vit. B_1.

Regarding yield, 'Tai So' presented the best values, whereas yield efficiency were quite similar for all the cultivars except for 'Brewster'. 'Tai So' showed the best qualitative performances as pomological traits (FW, TSSC and TA), flesh composition (PRO, TSG, ASH), mineral components, vitamin

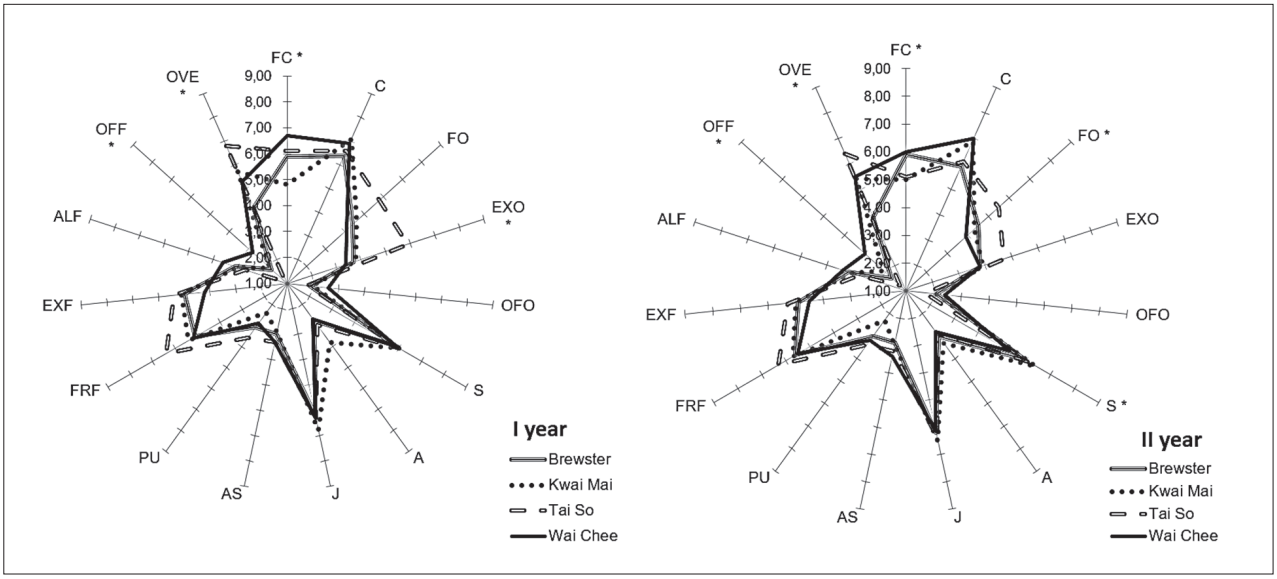

Figure 1. Spider plot of the sensory characteristic of the four litchi cultivars over two cropping seasons. The values marked with * indicate significant differences (P < 0.05). FC – Flesh colour; C – Consistency; FO – Fruity odour; EXO – Exotic fruit odour; OFO – Off odour; S – Sweet; A – Acid; J – Juiciness; AS – Astringent; PU – Pungent; FRF – Fruity flavour; EXF – Exotic fruits flavour; ALF – Flavour alcohol; OFF – Off flavour; OVE – Overall evaluation.

content and exotic fruit odor. 'Kwai Mai' was similar to 'Tai So' in TSS, TSG, Vit. B_1 and Vit. B_3 contents, and presented the best TSS/TA ratio. On the other hand, 'Wai Chee' produced the smallest fruits, that were characterized however, by the highest colour index.

The possibility of cultivating litchi in Sicily could be an economic opportunity (niche market) for growers. These fruits would be harvested when the export season from tropical countries ends and there is an opening in the market. Moreover, fresh litchi fruit would reach European markets within 24–48 h and maintain their high quality characteristics.

The results of our study show that litchi can be cropped for fresh fruit production in a Mediterranean climate. Over a two-year experiment, the results are quite promising: fruit reach a qualitative standard similar to that of varieties grown in a tropical environment. Further studies are still necessary to evaluate the effect of cultivation techniques and postharvest management as well as marketing and distribution on the overall commercial success and potential adoption by Italian farmers.

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