Table 2. Main phenological stages recorded on the four medlar cultivars grown in the experimental farm of Tuscia University (latitude 42°25'N, longitude 12°08'E, altitude 300 m).

Phenological stage	'Comune'	'Gigante'	'Goccia'	'Precoce'
Bud break	Mid March	Mid March	Mid March	Early-mid March
Sprouting	Early April	Early April	Mid-late March	Mid-late March
Swollen flower buds	Mid April	Mid April	Early-mid April	Early April
Full bloom	Mid-late May	Mid-late May	Mid-late May	Mid May
Fruit set and start fruit development	Early June	Early June	Late May - Early June	Late May
Ripeness (Harvesting time)	Early November	Late October	Early November	Late October

ue of 0.05 kg cm^{-2}. In 2014 all accessions except 'Precoce' showed the highest YE, contrarily to 2016, when the cultivars were characterized by a low production, with the only exception of 'Gigante' which was more steady for this character.

Khadivi et al. (2019) have obtained in their correlation between the traits detected on some Iranian biotypes that the yield was positively correlated with tree vigor, tree canopy size and branching, while it was negatively correlated with suckering. Our findings confirm the correlation between yield and tree vigor, as the cultivars 'Comune', 'Goccia' and 'Precoce' showed a higher YE when compared to 'Gigante', the cultivar investigated with the lowest vigor and yield.

Pomological traits

Similarly to what was observed by Ognjanov and Ceroviç (2004) on Serbian biotypes, the pomological traits of the fruits were significantly influenced by variety and year effects and by their interaction, as shown in Table 3. 'Gigante' was characterized by the highest size of fruits with a mean fruit weight of 41.03 g and a mean equatorial diameter and height of 46.61 and 34.98 mm, respectively. This accession showed also the biggest size of fruits in 2014 with mean values of almost 50.0 g.

On average, the fruits were smaller in 2016 for all accessions in comparison to other years of investigation, with the only exception of 'Goccia', that showed the smallest fruits in 2015.

The accession 'Precoce' showed the lowest values of the measured pomological traits with fruits characterized by a mean weight of 17.97 g and highlighting the lowest weight value on 2016 (14.54 g).

The average weight of fruits observed during the three year of investigation and expressed as mean of cultivars ranged between 30 g in 2014 and 24 g in the other two years

Table 3. Fruit weight, diameter, height shape index and seeds/fruit ratio of four cultivars of medlar ('Comune', 'Gigante', 'Goccia', and 'Precoce') over three years of investigation as means of 60 replicates ± standard deviation. Values followed by different letters are significantly different according to the Fisher's test ($p \leq 0.05$). (Significance: * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$).

Cultivar	Year	Weight (g)	Diameter (mm)	Height (mm)	Shape index	% Seeds
'Comune'	2014	$28.54^{b} \pm 4.65$	$39.41^{b} \pm 2.71$	$34.69^{b} \pm 1.88$	$0.88^{c} \pm 0.05$	7.42 ± 0.58
'Gigante'		$47.08^{a} \pm 2.56$	$48.71^{a} \pm 5.05$	$34.59^{b} \pm 2.43$	$0.71^{d} \pm 0.07$	7.67 ± 1.07
'Goccia'		$23.49^{c} \pm 4.09$	$35.18^{c} \pm 2.54$	$39.10^{a} \pm 2.26$	$1.11^{a} \pm 0.08$	8.54 ± 0.94
'Precoce'		$22.25^{c} \pm 4.51$	$35.69^{c} \pm 2.90$	$33.65^{c} \pm 2.38$	$0.94^{b} \pm 0.06$	10.77 ± 0.88
'Comune'	2015	$23.49^{b} \pm 5.64$	$36.08^{b} \pm 3.50$	$34.82^{b} \pm 2.93$	$0.96^{c} \pm 0.06$	10.07 ± 0.84
'Gigante'		$39.63^{a} \pm 1.44$	$46.22^{a} \pm 5.04$	$34.34^{bc} \pm 2.69$	$0.74^{d} \pm 0.07$	7.63 ± 1.38
'Goccia'		$18.81^{c} \pm 4.48$	$31.23^{c} \pm 2.95$	$38.16^{a} \pm 2.44$	$1.22^{a} \pm 0.09$	8.74 ± 1.43
'Precoce'		$17.13^{c} \pm 4.18$	$31.37^{c} \pm 2.82$	$33.59^{c} \pm 2.77$	$1.07^{b} \pm 0.07$	12.08 ± 1.33
'Comune'	2016	$21.33^{b} \pm 5.77$	$35.27^{b} \pm 3.39$	$33.22^{c} \pm 3.01$	$0.94^{c} \pm 0.07$	7.10 ± 1.39
'Gigante'		$36.39^{a} \pm 8.78$	$44.91^{a} \pm 4.48$	$36.03^{b} \pm 2.94$	$0.80^{d} \pm 0.06$	6.28 ± 1.25
'Goccia'		$21.64^{b} \pm 4.61$	$34.04^{b} \pm 3.15$	$39.23^{a} \pm 2.63$	$1.15^{a} \pm 0.09$	5.76 ± 1.27
'Precoce'		$14.54^{c} \pm 3.95$	$30.19^{c} \pm 3.07$	$31.60^{d} \pm 2.45$	$1.04^{b} \pm 0.06$	11.01 ± 1.65
Average cvs.	2014	$30.34^{a} \pm 12.36$	$39.75^{a} \pm 6.43$	35.51 ± 3.08	$0.91^{b} \pm 0.16$	$8.60^{ab} \pm 1.59$
	2015	$24.76^{b} \pm 11.36$	$36.23^{b} \pm 7.12$	35.23 ± 3.22	$1.00^{a} \pm 0,19$	$9.63^{a} \pm 2.07$
	2016	$23.47^{b} \pm 10.01$	$36.10^{b} \pm 6.49$	35.02 ± 4.00	$0.99^{ab} \pm 0.15$	$7.53^{b} \pm 2.48$
'Comune'	Average years	$24.45^{b} \pm 6.15$	$36.92^{b} \pm 3.67$	$34.24^{b} \pm 2.74$	$0.92^{c} \pm 0.07$	$8.19^{b} \pm 1.16$
'Gigante'		$41.03^{a} \pm 7.88$	$46.61^{a} \pm 5.09$	$34.98^{b} \pm 2.78$	$0.75^{d} \pm 0.08$	$7.19^{b} \pm 1.83$
'Goccia'		$21.31^{bc} \pm 4.78$	$33.48^{c} \pm 3.32$	$38.83^{a} \pm 2.48$	$1.15^{a} \pm 0.10$	$7.68^{b} \pm 1.80$
'Precoce'		$17.97^{c} \pm 5.29$	$32.41^{c} \pm 3.76$	$32.94^{c} \pm 2.70$	$1.01^{b} \pm 0.09$	$11.28^{a} \pm 1.40$
Source of variation						
Cultivar		***	***	***	***	***
Year		***	***	n.s.	***	***
Cultivar * Year		***	***	***	***	n.s.

Table 4. Total soluble sugars and main single soluble sugars in the bletted flesh of four medlar cultivars expressed in g 100 g^{-1} DW. Values are means of three replicates ± standard deviation. Values followed by different letters are significantly different according to the Fisher's test ($p \leq 0.05$).

Cultivar	Total sugars (g 100 g^{-1} DW)	Fructose (g 100 g^{-1} DW)	Glucose (g 100 g^{-1} DW)	Sucrose (g 100 g^{-1} DW)	Sorbitol (g 100 g^{-1} DW)
'Comune'	53.31^{b} ± 0.75	29.60 ± 1.50	18.78^{bc} ± 0.81	0.03^{a} ± 0.006	4.49^{d} ± 0.23
'Gigante'	54.46^{b} ± 1.11	30.44 ± 1.02	17.37^{c} ± 1.04	0.02^{b} ± 0.001	6.29^{a} ± 0.30
'Goccia'	59.09^{a} ± 1.36	32.20 ± 1.61	21.44^{a} ± 1.46	0.02^{b} ± 0.002	5.02^{c} ± 0.09
'Precoce'	58.54^{a} ± 0.81	32.57 ± 1.08	20.05^{ab} ± 1.85	0.03^{a} ± 0.003	5.55^{b} ± 0.20

(Table 3). These values were higher than those observed by Akbulut et al. (2016) for Turkish biotypes, while the fruits size were similar to those observed by Altuntaş et al. (2013).

The seeds/fruit ratio was influenced by the variety and year, and its value, expressed as mean of the three years, ranged from 7.19% for 'Gigante' to 11.28% for 'Precoce'. These cultivars where thus characterized by the highest and lowest incidence of pulp in the fruits respectively, as confirmed by the comparison of this trait together with the fruit weight.

Furthermore, the seeds/fruit ratio was stable in the years for the accessions 'Gigante' and 'Precoce', whereas showed variability for the other cultivars, as for 'Goccia' that was characterized by the lowest seed incidence in 2016 (5.76%) compared to the other years (slightly higher than 8.5%) and as for 'Comune', characterized by a seed incidence higher than 2.5% in 2015 (10%), compared to the other two years.

Considering the shape index, expressed as fruit height and equatorial diameter ratio, 'Goccia' can be classified as conical-elongated fruit cultivar according to the fruit shape descriptor (Bignami, 1998; Bellini et al., 2007), whereas 'Comune' and 'Precoce' have spherical, and 'Gigante' flat fruit shape, as shown in Figure 1. On average, all these "commercial" cultivars showed fruits bigger than the fruits collected in the "wild types" (Figure 1).

Sugar and acid characteristics in bletted fruits

Total sugars content in the lyophilized flesh of bletted fruits was significantly different among cultivars ranging between 59.09 g 100 g^{-1} DW in 'Goccia' to 53.31 g 100 g^{-1} DW in 'Comune' (Table 4). Fructose was the main sugar in the flesh of all cultivars, representing about 30% of the DW. Glucose was the more variable soluble sugar in the bletted flesh ranging from 21.44 g 100 g^{-1} DW in 'Goccia' to 17.37 g 100 g^{-1} DW in 'Gigante'. Quite high differences were detected for sorbitol content that showed the highest values in 'Gigante' (above 6.0 g 100 g^{-1} DW), meanwhile the sucrose showed the lowest levels with value of 0.2–0.3 g 100 g^{-1} DW in all cultivars. Sorbitol combines sweetener properties with a lower effect on blood sugar level compared to other sugars. Consequently, the good sorbitol content makes the medlar interesting for the potential benefits of this polyalcohol on human health, when the right fructose: glucose: sorbitol ratios and the consumption thresholds are respected (Livesey, 2003). The presence of fructose and glucose as main medlar sugars has been reported also for Turkish biotypes (Glew et al., 2003).

Furthermore, by comparing the detected soluble sugars content with those available in literature for medlar (Glew et al., 2003; Altuntaş et al., 2013) emerged as the sugars content in our analyses were significantly higher. This is due to the different stage of over-ripening of fruits that strongly influences the flesh composition, and while our samples were analyzed when completely bletted, in other works the fruits were not completely overripe and showed a white or only little brown flesh.

It should also be highlighted that even if elsewhere it has been found a high soluble solid content in the flesh of medlar (Ercisli et al., 2012) its sugar content is significantly lower in comparison to other pome fruits as apple and pear.

Total organic acid content (Table 5) was highest in 'Gigante' (5.37 g 100 g^{-1} DW) and was lowest in 'Goccia' (3.19 g 100 g^{-1} DW), which showed a faster ripening process.

Malic was the main organic acid showing notable differences between cultivars, and ranging from 3.20 g 100 g^{-1} DW in 'Comune' and 'Precoce' to 1.73 g 100 g^{-1} DW to 'Goccia' (Table 5). A noticeable content of quinic acid was also present in the bletted flesh with values included by 1.33–1.92%. Citric and succinic acids were detected only in traces.

The organic acid contents were similar to those found by Glew et al. (2016) and the authors observed as the acids levels were high when fruits were still hard and unripe, while the level of malic acid increased at fruits partly soft and all acids leveled off at the end of post-harvest period.

Sensory evaluation

The sensory profile of bletted flesh showed remarkable differences among cultivars (Figure 3). Sensory analysis revealed a general high appreciation for 'Goccia' and a negative judgement for 'Gigante'. The scores obtained by 'Goccia' were high for sweetness and aroma and low for acidity, astringency and alcoholic. Conversely, 'Gigante' has been perceived as characterized by scarcely sweet, very dry and acid and with

Table 5. Total organic acids and main single organic acids in the bletted flesh of four medlar cultivars expressed in g 100 g^{-1} DW. Values are means of three replicates ± standard deviation. Values followed by different letters are significantly different according to the Fisher's test ($p \leq 0.05$).

Cultivar	Total acids (g 100 g^{-1} DW)	Malic (g 100 g^{-1} DW)	Citric (g 100 g^{-1} DW)	Quinic (g 100 g^{-1} DW)	Succinic (g 100 g^{-1} DW)
'Comune'	5.16^{a} ± 0.14	3.20^{a} ± 0.30	0.10^{a} ± 0.010	1.82^{ab} ± 0.18	0.03 ± 0.001
'Gigante'	5.37^{a} ± 0.24	3.39^{a} ± 0.30	0.02^{c} ± 0.002	1.93^{a} ± 0.19	0.02 ± 0.003
'Goccia'	3.19^{c} ± 0.17	1.73^{b} ± 0.28	0.01^{c} ± 0.001	1.42^{bc} ± 0.29	0.03 ± 0.005
'Precoce'	4.57^{b} ± 0.17	3.20^{a} ± 0.18	0.04^{b} ± 0.001	1.32^{c} ± 0.18	0.03 ± 0.005

fibrous flesh. These results of perception have a good correspondence with the analytical data of flesh composition (Tables 4 and 5), even if an accentuation or attenuation of the level of sensory perception, especially for the sweetness, can occur due to the different relationship between acids and sugars (Bignami et al., 2003), and for the influence of astringency as it has been verified to be negatively correlated with the perception of sweetness (Fontoin et al., 2008).

Accession 'Comune' was appreciated for the aroma, and 'Precoce' was perceived for fermented and astringency.

Among the sensory attributes, "sweetness" and "alcoholic" received lower scores with respect to "fermented", "acidity" and "aroma", which seem to better characterize the medlar fruit.

'Comune' and 'Goccia' were the most appreciated cultivars for the external fruit appearance both at early ripening stage, when the fruits are generally sold, and at bletting. The medium size and the regular round shape are probably the traits making 'Comune' and 'Goccia' more appealing than the other cultivars. Contrariwise, the high size was not enough to make 'Gigante' appealing, also because of the frequent presence of cracking.

Conclusions

An overall analysis of the vegetative, productive, pomological and qualitative traits collected during the investigation underlined the cultivars 'Comune', 'Goccia' and 'Precoce' as suitable for a commercial cultivation due to the high production and high fruits quality. On general, the level of medlar production is in line with data published in the past by Monastra and Paesano (1991) in Italian environment.

The cultivar 'Comune' is interesting for its high and constant yield, for its fruit size and shape and for its aromatic taste and low flesh fibrousness. The big size of 'Gigante', a trait often associated to the fruit cracking (Ognjanov and Ceroviç, 2004), its insufficient taste and high flesh fibrousness emerged during the sensory analysis, penalized the cultivar that also showed a low productivity.

High sweetness, low acidity and fine texture contribute to the appreciation of the fruits, whereas dry and fibrous flesh and low sweetness negatively affect cultivar judgement.

The introduction of medlar into fruit growing for the commercial exploitation needs an accurate cultivar choice. The differences of exterior and inner quality were clearly perceived and could positively or negatively influence the potential consumer. Furthermore, sensory attributes such as sweetness, acidity, flavor and texture can influence the quality of processed products, such as jams, jellies, schnaps and liqueurs, which represent interesting uses of medlar fruits.

The high rusticity of the species, able to adapt to poor soils and to survive at very low winter temperatures, its easy orchard management, the pleasant and delicate taste of the overripe fruit (Bignami et al., 2008), its high nutritional value (Barbieri et al., 2011) and the recent rediscovery of the so-called "forgotten fruits" are all valid requisites for promoting the medlar cultivation in specialized orchards.

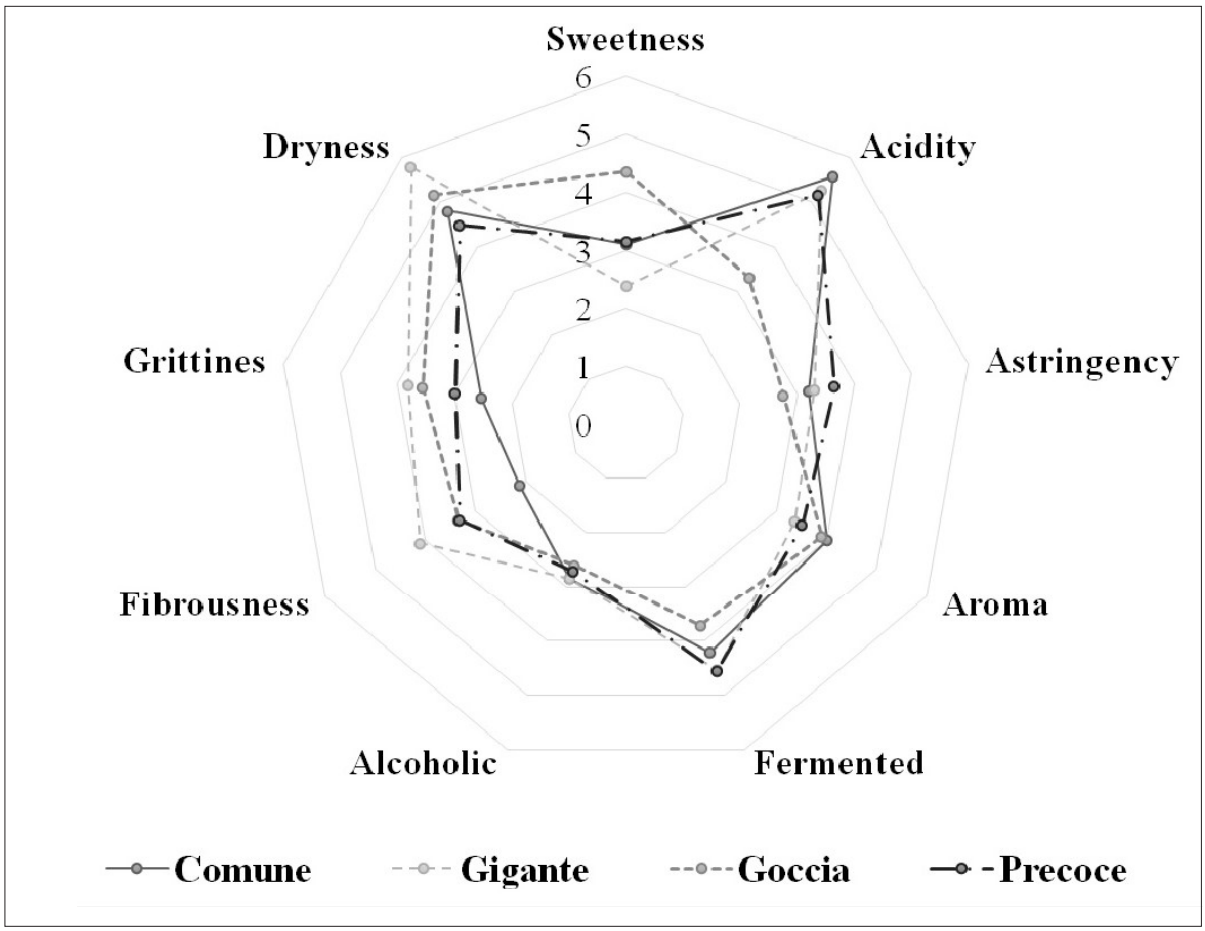

Figure 3. Sensory profile of bletted flesh of the four medlar cultivars expressed as mean of the values assigned by the panellists for each attribute.

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