Four New Persian Walnut Cultivars of Iran: Persia, Caspian, Chaldoran, and Alvand

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Persian walnut (*Juglans regia* L.) is the second-most important nut crop grown in Iran. The number of walnut trees in that country is estimated to be more than 20 million, mostly seedlings, distributed on

borders of farms and orchards or expanded in valleys. Total production of in-shell walnut is estimated at 400,000 t, and Iran is considered the third largest walnut producer in the world. Use of walnut seedling trees throughout the centuries has provided unique opportunities for breeders to select promising genotypes (Hassani, et al., 2014; McGranahan and Leslie, 2005; Vahdati et al., 2019). We report the main characteristics of four newly released commercial walnut cultivars—Persia, Caspian, Chaldoran, and Alvand—in Iran that are characterized by high yield, lateral fruitfulness, and early harvest.

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In Iran, the walnut breeding program started in 1984 through the selection of native germplasm. This project led to the selection of some superior genotypes, of which two new cultivars, Jamal and Damavand, were released in 2010 (Hassani et al., 2012a, 2012b). The second phase of this program, with the aim of selecting for late leafing and lateral-bearing cultivars, was carried out during early 2000. A total of 39 promising walnut genotypes were selected from more than 41,000 ha of walnut plantations in the Alborz, Qazvin, Zanjan, West Azarbaijan, Kerman, Khorasan Razavi, Semnan, and Yazd Provinces. In 2006, the genotypes were grafted onto seedling rootstocks and were planted at a 7 × 7-m planting distance (square system) in a 6 × 7 lattice experimental design, with two replications and three trees per plot. The experimental orchard was established in Karaj (lat. 35.760560°N, long. 50.96843°E; elevation, 1268 m above sea level) and at the Rabor Walnut Research Station in Kerman Province (lat. 29.26264°N, long. 57.04825°E; elevation, 2300 m above sea level). Three commercial cultivars, including ‘Chandler’, ‘Jamal’ and ‘Ronde de Montignac’, were included in this trial as reference cultivars. Phenological and pomological characteristics of promising genotypes were studied until 2018. Four new cultivars were released in 2019 (Hassani et al., 2019).

Methods

Phenological and pomological traits of the selected cultivars were evaluated using International Plant Genetic Resources Institute (1994) and International Union for the Protection of New Varieties of Plants (1999) walnut descriptors. Moreover, the relative susceptibility of the new cultivars to anthracnose was tested as described by Dastjerdi and Hassani (2009). Blight and bark canker diseases were also evaluated as described by Silsepur et al. (2011) and Soleymani et al. (2019).

Description

‘Persia’. ‘Persia’ is characterized by late leafing behavior (around ‘Chandler’ leafing date), which helps to avoid late-spring frosts (Supplemental Table 1, Supplemental Fig. 1). The protogynous flowering habits of this cultivar allows it to cross-pollinate with ‘Chandler’ (Supplemental Fig. 1). It has a lateral bearing habit (Fig. 1), and most of the buds are productive (60% to 80%). Vigor is intermediate. Yield in this cultivar is as high as ‘Chandler’ (Supplemental Table 1). Nut size is medium and nut weight is 10.5 g, and the nut has a thin shell (0.93 mm) and a greater percentage of kernel (63%) in comparison with ‘Chandler’ and other cultivars (Supplemental Table 2). The kernel is removed easily from the shell and has a light and extralight color. Kernel plumpness is good. The ripening time is early-medium, about 25 d earlier than ‘Chandler’ (Supplemental Table 1, Supplemental Fig. 1). This cultivar is moderately resistant to anthracnose, bark canker, and blight.

Fig. 1. Fruit of newly released walnut cultivars at maturity in Iran. *Ch, Chandler.

'Caspian'. 'Caspian' is characterized by a relatively late leafing property, which helps it to avoid late-spring frosts. This variety leafs out at the same time as 'Chandler' (Supplemental Table 1, Supplemental Fig. 1). The protogynous flowering habit of 'Caspian' allows it to cross-pollinate with 'Chandler' (Supplemental Fig. 1). It has a lateral bearing habit (Fig. 1), and lateral buds are 60% to 80% fruitful. 'Caspian' yield is high and very similar to 'Chandler' (Supplemental Table 1). Nut weight is medium (average, 9.2 g). It has a thin shell (0.99 mm) and a kernel that consists of $\approx$ 56% of the nut weight (Supplemental Table 2). Plumpness, light and extralight color, along with good removal are the most important traits of the 'Caspian' kernel. Its ripening time is early-medium, 23 d earlier than 'Chandler' (Supplemental Table 1, Supplemental Fig. 1). This cultivar has intermediate vigor and is moderately resistant to anthracnose and blight.

'Chaldoran'. 'Chaldoran' has a tree with intermediate vigor, and precocious and high fruit-bearing potential (Supplemental Table 1, Fig. 1; Rezaee et al., 2008). The lateral buds are 90% to 100% fruitful. The nuts are large (average weight, 13 g) (Supplemental Tables 1 and 2). The leafing date is early to medium, and products may get damaged by late-spring frost, but because this cultivar has a long flowering period, it can produce enough crop after spring frosts when pollen is available. 'Chaldoran' is early ripening (Supplemental Fig. 1). Kernels are large and include 56% of the nut weight. The kernel is an amber color and is removed easily from the shell (Supplemental Table 2). This cultivar is moderately tolerant to blight as well as anthracnose.

'Alvand'. Tree growth vigor is very low in 'Alvand' (Fig. 1). This feature makes the cultivar suitable to be planted densely, at distances of 4 to 5 m. 'Alvand' is precocious, has a good bearing potential on lateral buds (Fig. 1), and 90% to 100% of the buds are

fruitful (Supplemental Table 1). The leafing date is early to medium, and products may be damaged by late-spring frost, but because it has a long flowering period, similar to 'Chaldoran', it could produce enough crops after spring frosts if pollen is available. 'Alvand' is an early-ripening cultivar (Supplemental Fig. 1). Kernels are a medium size (nut weight average, 11.3 g), and the kernel weight is 50% of the nut weight. Kernels are removed easily from the shell (Supplemental Table 2). This cultivar is relatively sensitive to anthracnose, bark canker, and blight.

Availability

Because of the late leafing and early-to-medium ripening habits of 'Persia' and 'Caspian', they can be recommended for walnut-growing areas with late-spring and early-autumn frosts; however, 'Chaldoran' and 'Alvand' are more suitable for regions with less late-spring frost risk.

'Persia', 'Caspian', 'Chaldoran', and 'Alvand' were released officially in Mar. 2019 by the Horticultural Sciences Research Institute of Iran (Hassani et al., 2019), and are in the stage of propagation.

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Supplemental Fig. 1. Leafing date, pollen shedding period, female flower receptivity period, and fruit ripening date of four released cultivars: Persia, Caspian, Alvand, and Chaldoran. Reference cultivar: Chandler.

Supplemental Table 1. Tree and phenological characteristics of new walnut cultivars.

Characteristics	Caspian	Persia	Chandler	Alvand	Chaldoran
Date of budbreak (mean $\pm$ SD)	6 Apr. $\pm$ 3.0 d	3 Apr. $\pm$ 3.8 d	4 Apr. $\pm$ 4.7 d	23 Mar. $\pm$ 7.9 d	22 Mar. $\pm$ 7.3 d
First male bloom date (mean $\pm$ SD)	20 Apr. $\pm$ 1.5 d	17 Apr. $\pm$ 2.9 d	12 Apr. $\pm$ 4.5 d	3 Apr. $\pm$ 8.9 d	1 Apr. $\pm$ 8.1 d
First female bloom date (mean $\pm$ SD)	12 Apr. $\pm$ 3.7 d	10 Apr. $\pm$ 2.9 d	21 Apr. $\pm$ 2.8 d	6 Apr. $\pm$ 10.9 d	4 Apr. $\pm$ 7.0 d
Fruit ripening date (mean $\pm$ SD)	2 Sept. $\pm$ 5.0 d	31 Aug. $\pm$ 4.4 d	25 Sept. $\pm$ 7.0 d	25 Aug. $\pm$ 4.8 d	26 Aug. $\pm$ 4.8 d
Harvest time (mean $\pm$ SD)	15 Sept.	9 Sept.	6 Oct.	4 Sept.	4 Sept.
Tree vigor	Intermediate	Intermediate	Intermediate	Low	Intermediate
Growth habit	Semierect	Semierect	Semierect	Semierect	Semierect
Branching	Dense	Dense	Dense	Dense	Dense
Shoot color	Brown	Brown	Blackish	Brown	Brown
Leaflet shape	Narrow elliptic	Narrow elliptic	Narrow elliptic	Elliptic	Elliptic
Rachis persistence	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate
Husk persistence after nut fall	Slight	Slight	Slight	Slight	Slight
Lateral bud flowering (%)	60–80	60–80	80–90	90–100	90–100
Dichogamy	Protogynous	Protogynous	Protandrous	Protandrous	Protandrous
Duration of female bloom overlapped by staminate bloom (%)	40–70	45–65	0–10	40–70	35–45
Catkin abundance	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate
Female flower abundance	Heavy	Heavy	Heavy	Heavy	Heavy
Yield (g·cm ⁻² of trunk cross area)	20.4 $\pm$ 29.3	20.6 $\pm$ 3.25	20.5 $\pm$ 3.4	45.9 $\pm$ 7.93	52.2 $\pm$ 6.4
Estimated yield	High	High	High	Very high	Very high

Results are the average of experimental data collected from 2015 to 2018.

Supplemental Table 2. Nut and kernel characteristics of the released walnut cultivars.

Characteristics	Caspian	Persia	Chandler	Alvand	Chaldoran
Nut weight (g, mean $\pm$ SD)	9.2 $\pm$ 1.69	10.5 $\pm$ 2.27	9.2 $\pm$ 1.94	11.3 $\pm$ 2.30	13 $\pm$ 2.49
Kernel weight (g, mean $\pm$ SD)	5.2 $\pm$ 0.95	6.6 $\pm$ 1.34	3.9 $\pm$ 1.08	5.5 $\pm$ 1.06	7.3 $\pm$ 1.32
Kernel percentage (mean $\pm$ SD)	56 $\pm$ 7.39	63.1 $\pm$ 7.41	43.6 $\pm$ 5.41	49.7 $\pm$ 8.10	56.5 $\pm$ 5.67
Nut length (mm, mean $\pm$ SD)	34.4 $\pm$ 2.6	36.2 $\pm$ 2.4	35.7 $\pm$ 3.0	36.8 $\pm$ 2.6	41.0 $\pm$ 2.4
Nut diameter (mm, mean $\pm$ SD)	31.8 $\pm$ 2.5	32.7 $\pm$ 4.1	32.2 $\pm$ 3.0	38.0 $\pm$ 3.1	35.5 $\pm$ 3.3
Nut width (mm, mean $\pm$ SD)	30.2 $\pm$ 2.0	32.0 $\pm$ 2.6	31.7 $\pm$ 2.3	37.8 $\pm$ 3.1	35.5 $\pm$ 2.4
Nut size	Medium	Medium	Medium	Medium	Large
Nut shape, longitudinal section through suture	Elliptic	Elliptic	Ovate	Circular	Elliptic
Nut shape, longitudinal and perpendicular to suture	Broad elliptic	Elliptic	Long trapezoid	Circular	Trapezium
Nut shape, cross-section	Oblate	Oblate	Circular	Oblate	Circular
Nut index of roundness	Medium	Medium	Medium	Medium	Low
Nut shape, base perpendicular to suture	Rounded	Rounded	Rounded	Truncate	Cuneate
Nut shape, apex perpendicular to suture	Rounded	Rounded	Rounded	Rounded	Rounded
Nut, prominence of apical tip	Weak	Weak	Weak	Weak	Weak
Nut, position of pad on suture	On upper 2/3	On upper 2/3	On upper 2/3	On upper 2/3	On upper 2/3
Nut, prominence of pad on suture	Weak	Weak	Weak	Weak	Medium
Nut, width of pad on suture	Narrow	Narrow	Narrow	Broad	Medium
Nut, depth of groove along pad on suture	Medium	Medium	Medium	Medium	Medium
Nut, structure of surface of shell	Moderate	Moderate	Moderate	Moderate	Moderate
Shell strength	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate
Shell thickness (mm, mean $\pm$ SD)	0.99 $\pm$ 0.28	0.93 $\pm$ 0.32	1.17 $\pm$ 0.29	0.99 $\pm$ 0.42	1.21 $\pm$ 0.38
Shell seal	Intermediate	Intermediate	Intermediate	Intermediate	Intermediate
Ease of removal of kernel halves	Easy	Easy	Very easy	Very easy	Easy
Kernel color	Light	Light	Light	Amber	Amber
Kernel fill	Well	Well	Poor	Poor	Well
Kernel plumpness	Plump	Plump	Thin	Moderate	Plump
Kernel size	Medium	Large	Medium	Medium	Very large