Genet Resour Crop Evol (2017) 64:611–640
DOI 10.1007/s10722-016-0485-x

BOOK REVIEW

A review of genetic resources of almonds and stone fruits (*Prunus* spp.) in Iran

Ali Gharaghani · Sahar Solhjoo · Nnadozie Oraguzie

Received: 2 August 2016 / Accepted: 20 December 2016 / Published online: 17 January 2017

Abstract Iran is amongst the countries in the world widely known for cultivation of *Prunus* spp. (or stone fruits). It is both a centre of origin and diversity of the stone fruits. Numerous wild species as well as many cultivars and landraces of these fruit crops are important genetic resources today in Iran and can be used for improvement and breeding of scion and rootstock cultivars which are resistant to many biotic and abiotic stresses through modern genomics and genetic technologies. This paper discusses the distribution, ethno-botany, diversity and utilization of wild and domesticated genetic resources of stone fruits including almond (*Prunus dulcis* (Miller) D. A. Webb.), peach and nectarine (*P. persica* Batsch), European and Japanese plum (*P.* × *domestica* L., and *P. salicina* L., respectively), sweet and sour cherry (*P. avium* L., and *P. cerasus* L., respectively), and apricot (*P. armeniaca* L.), all of which are members of the Rosaceae family. The goal of this paper is to highlight the importance of Iran as a main contributor to the diversity of Prunus genetic resources in the world, as well as, present major achievements regarding identification, collection, evaluation, conservation and utilization of this valuable genetic resource in Iran.

Keywords Center of origin · Distribution · Endemic species · Genetic resources · *Prunus* spp. · Stone fruit · Utilization

A. Gharaghani (✉) · S. Solhjoo
Department of Horticultural Science, College of Agriculture, Shiraz University, Shiraz, Iran
e-mail: agharghani@shirazu.ac.ir

S. Solhjoo
e-mail: saharsolhjo@Yahoo.com

A. Gharaghani
Drought Research Center, College of Agriculture, Shiraz University, Shiraz, Iran

N. Oraguzie
Department of Horticulture, Washington State University, Irrigated Agriculture, Research and Extension Center, 24106 N Bunn Road, Prosser, WA 99350, USA
e-mail: noraguzie@wsu.edu

Introduction

Iran comprises a land area of 1.64 million km^2. It lies in the northern part of the temperate zone, between latitudes 25°03′ to 39°47′N and longitudes 44°14′ to 63°20′E. It is bordered on the north by Armenia, Azerbaijan, Turkmenistan, and the Caspian Sea (the Caucasus mountains, Middle Asian natural regions), on the east by Afghanistan and Pakistan, on the south by the Persian Gulf and the Gulf of Oman, and on the west by Iraq and Turkey (Anatolian and Mesopotamian regions). The existence of high mountains (esoecially the Elborz range) in the north, the Zagros range in the west and southwest, and the eastern mountains which surround the Iranian plateau, provides Iran with rugged mountains and spectacular terrains (Abolghasemi 2011) (Fig. 1). The height of some of the mountains exceeds 5000 m. There are wide plains including low coastal lands (the Caspian Sea, 26 m below sea level) both in the north and south of the country (Firuz 1974). Most of Iran is located in the Palaearctic region considered to be the centre of origin of many crop genetic resources of the world, including many original land races of commercially valuable crop species. The Iranian vascular plant flora comprises approximately 8000 species, with about 20% being endemic, based on the published and forthcoming volumes of Flora Iranica (Rechinger 1963–2001).

Prunus spp. (Rosaceae) comprises over 200 species of deciduous and evergreen trees and shrubs with several members that are economically important fruit and nut crops (Chin et al. 2014). The most recent classification of Rosaceae proposed by Potter et al. (2007) grouped *Prunus* as the only genus in the tribe Amygdaleae within an expanded subfamily Spiraeoideae. The most widely accepted infrageneric classification of *Prunus* by Rehder (1940) consists of five subgenera: *Amygdalus*, *Prunus*, *Cerasus*,

Fig. 1 The map of Iran with the main mountain ranges, plains, counties and locations bordering neighboring countries

Laurocerasus, and *Padus*: The subgenus *Amygdalus*, to which diploid peaches and nectarins (*P. persica* Batsch) and diploid almonds (*P. dulcis* (Mill.) D. A. Webb.) belong, and the subgenus *Prunus*, which includes section *Prunophora* comprises diploid Japanese plums (*P. salicina* L.) and hexaploid European plums (*P.* × *domestica* L.) and section *Armeniaca* containing diploid apricots (*P. armeniaca* L.), and the subgenus *Cerasus* comprising diploid sweet cherry (*P. avium* L.) and tetraploid sour cherry (*P. cerasus* L.). Recently, Shi et al. (2013) divided *Prunus* L. into three subgenera: *Prunus* (consist of almond, peaches, apricoat and plums which have been classified into the different sections), *Cerasus* (including cherries), and *Padus*.

Iran is amongst the countries in the world widely known to produce tree fruits belonging to the *Prunus* spp. Major achievements in identification, collection and breeding of fruit crops in the genus Prunus in Iran have been recorded by higher education and research institutes in Iran including the horticultural research stations in Sahand (in the East Azerbaijan province), Shahrood (in Semnan province), Karaj–Kamalshahr (in Alborz province), Mashhad (Khorasn-e Razavi province) and Tehran university (in the department of horticultural sciences). Many members of the genus *Prunus* are widely cultivated for fruit and as ornamental trees. The fruit is commonly regarded as the stone fruit. In botany, the stone fruit (or drupe) is an indehiscent fruit in which an outer fleshy part (exocarp or skin and mesocarp or flesh) surrounds a shell (the pit, stone) of a hardened endocarp with a seed (kernel) inside (Khoshkhui et al. 2004). However, the almond is different from other stone fruits and is cultivated as a nut crop. The edible portion is the seed while the almond fruit is a drupe and not a true nut.

Almond

Almond, *P. dulcis* (Mill.) D. A. Webb. [syn. *P. amygdalus* (L.) Batsch] (Fig. 2) is an economically important nut crop in warm temperate regions. Almond species are deciduous trees (low or tall) or shrubs (with various heights) that grow in semi-arid places, stepps and as a belt along margins of xerophytic forests (e.g. the *Quercus* forests of the Zagros mountain) (Attar et al. 2009). They also grow on rocky mountains or limestone slopes (Browicz and Zohary 1996) at elevations ranging from ca 500 m above sea level in the southern mountains of Iran in the Bushehr province to 3800 m above sea level on the Taftan mountain in the Sistan–Baluchistan province in southeast Iran (Attar et al. 2009). *P. dulcis*, the cultivated almond is thought to have originated in the arid mountainous regions of Central Asia (Gradziel et al. 2001). Several species are also found in these mountainous areas, from the Tian Shan Mountains of western China, through Afghanistan, Kurdistan, and Turkestan and into Iran and Iraq (Gradziel 2011). Also, *P. fenzliana* Fritsch, *P. bucharica* (Korsh) B. Fedtsch. and *P. argentea* Lam., from these regions are described as wild species most closely related to almonds and may be the ancestral species of the modern cultivated almond (Gradziel et al. 2001, 2011). The exact origin of almonds has been difficult to ascertain and several hypotheses have been advanced concerning the origin. Evreinoff (1958) first suggested that the cultivated almond originated by hybridization among *P. fenzliana* Fritsch and probably *P. bucharica* (Korsh) B. Fedtsch. and *P. kuramica* (Korsh) Kitam. This theory has been supported by molecular data based on nuclear and chloroplast DNA markers, morphological and habitat studies in *Prunus* species (Ladizinsky 1999). Simple sequence repeat (SSR) marker analysis (Zeinalabedini et al. 2010) suggested that *P. fenzliana* Fritsch could be the most plausible progenitor of the cultivated almonds. Furthermore, as the almond moved toward the mediterranean region, new hybridizations might have occurred, especially with the wild mediterranean species, *P. webbii* (Spach) Vierh. (Socias i Company 1990), resulting in some of the almond populations found along the northern border of the mediterranean sea, from Greece and the Balkans to Spain and Portugal. However, according to Fernández i Martí et al. (2015) there could be a disconnection between almond and the related wild species despite the gene flow from wild relatives into almond. So further research is needed to test the hypothesis on the origin of cultivated almonds thought to have arisen as a result of natural hybridizations of wild species.

Although almond is one of the most important perennial nut crops in the arid and semi-arid regions of Iran, almond production in Iran is based on locally adapted clones, with minimum to no inputs, and managed traditionally (Sorkheh et al. 2009a). Iran with 41, 261 ha of harvestable area and 87, 281 t in production, ranked number 5 in the world in almond

Fig. 2 Flower and fruit of almond [*P. dulcis* (Mill.) D. A. Webb.]

production after USA, Australia, Spain and Morocco in 2013 (FAOSTAT 2016). About 72% of almond production (rainfed and irrigated orchards) occurs in Fars, Chaharmahal–Bakhtiari, Khorasan, Isfahan and Kerman provinces (Ministry of Agriculture 2014). In Iran, almond is called "Badam".

Wild and domesticated genetic resources

Many wild almond species including 20 wild species (Mozaffarian 2005) and six inter-specific hybrids have been reported in Iran (Khatamsaz 1992) indicating that Iran is within the centre of origin of almonds. Most of these species are found in Azarbayjan, Chaharmahal–Bakhtiari, Kerman and Fars provinces (Rahemi 2001). Seventeen (11 wild species and 6 inter-specific hybrids) of these are endemic to Iran including *P. glauca* (Browicz) A. E. Murray, *P. runemarkii* Eisenman (*Amygdalus reticulata* Runem. et Khat.), *P. haussknechtii* (Bornm.) C. K. Schneid., *P. elaeagnifolia* Spach, *P. wendelboi* (Freitag) Eisenman, *P. eburnea* Spach, *P. pabotii* (Browicz) Eisenman, *P. kurdistanica* (Attar, Maroofi et Vafadar) Eisenman, *P. orazii* (Maroofi, Attar et Vafadar) Eisenman, *P. lycioides* var. *horrida* (Spach) C. K. Schneid., *P. spinosissima* (Bunge) Franch. var. *urumiensis* Bornm., *P.* × *keredjensis* Browicz, *P.* × *iranshahrii* (Khat.) Eisenman, *P.* × *mozaffarianii* (Khat.) Eisenman, *P.* × *yasujensis* (Khat.) Eisenman, *P.* × *podperae* (Woron.) Náb., and *P.* × *kamiaranensis* (Khat. et Assadi) Eisenman (Table 1) (Khatamsaz 1992; Mozaffarian 2005; Attar et al. 2009; Eisenman 2015).

Almonds have been cultivated from seeds for centuries in Iran. The existence of a large number of trees grown from seed under various ecological conditions provides an invaluable source for varietal selections. The most important indigenous cultivars include 'Mamaei', 'Rabi', 'Sefid', 'Monagha', 'Sangi', 'Dobahre' and 'Tajeri'. These are typically early flowering, however, due to late spring frost, the flowers are often destroyed. So, breeding for cold hardiness and late flowering has often been an objective in almond breeding programs.

Evaluation and use of genetic resources

Almond breeding in Iran was started by Chaichi in 1969 at the Sahand Horticulture Research Station in East Azarbayjan province. Following the evaluation of foreign cultivars and locally selected genotypes, a crossing program was initiated to develop late blooming cultivars resulting in the release of three cultivars including 'Azar', 'Shekofeh' and 'Harir' (Chaichi and Eskandari 1999). In addition, 'Sahand' was introduced from the selection program including local cultivars (Chaichi 1999). In 2009–2010, new superior genotypes including 'Eskandari' and 'Araz' at the Sahand research station (Eskandari and Majidazar 2009) and 'Saba' and 'Aidin' at the Karaj research station were introduced from new cross programs. These cultivars are all late blooming (Table 2). In addition, 4000 progenies from 20 cross combinationss involving self-compatible cultivars and late blooming cultivars have been developed in order to obtain late blooming and self-compatible cultivars with high quality. These crosses have been under evaluation in Karaj, Sahand and Shahrekord research stations (Imani 2015).

Iran is extremely rich in wild almond species. Sorkheh et al. (2009b) reported that all the species are self-incompatible with bitter or slightly bitter seeds. These wild species provide an enlarged pool of available germplasm which possess desired

Table 1 Tree and fruit characteristics and distribution of almond species in Iran. Adapted from Khatamsaz (1992), Mozaffarian (2005), Attar et al. (2009)

Species	Tree characteristics	Fruit properties	Distribution
P. dulcis (Mill.) D. A. Webb.	Tree up to 8 m tall, current twigs: glaborous, green then reddish brown in color. Previous year's twigs are gray in color	Oval-diagonal to oval-oblong, bezel and downy fruits, oblong tip, 2.5–5 cm in length and 1.5–3 cm in diameter, holey and boat-shaped shell without longitudinal groove or with small groove at base	Mainly in the north west, west and south of Iran including Fars, Azerbayjan, Kurdistan, Markazi, Isfahan, Yazd, Kermanshah, Tehran and Lurestan provinces. Local name: bitter or sweet badam
P. trichamygdalus Hand.-Mazz.	Thornless shrub or tree with glaborous and greenish brown current twigs, previous year twigs are gray in color	Oval fruits with short velvet hair and drawn tip, fruits up to 22 mm in length and 15 mm in diameter, boat-shaped and holey shell	West of the country in the west Azerbayjan province. Local name: Badame Makhmali
P. wendelboi (Freitag) Eisenman*	Thornless trees up to 4 m tall, young shoots are glaborous and olive-brown in color, 1 year's shoots are glossy and brownish gray in color	Elliptical fruit with yellow velvet thorn, fruits 15–20 mm in length and 10–13 mm in diameter, oval shell with rounded tip and base	Endemic to Iran, in the south including Hormozgan and Sistan–Baluchistan provinces. Local name: Archan or badame Genuiye
P. korshinskyi Hand.-Mazz.	Thorny trees or shrubs up to 4 m long with glaborous current twigs	Flat ovate fruit with small tip and covered with short yellow hair, fruits 15–30 mm in length and 10–25 mm in diameter, shell without longitudinal groove and oblong holes	North west of Iran in the West Azerbayjan province
P. fenzliana Fritsch	Small tree up to 5 m tall with thornless and purple young shoots and 1 year gray shoots	Oval or almost round and downy fruits, up to 25 mm in length and 15 mm in diameter, boat-shaped and flat shell with 2 longitudinal grooves	North west of Iran in the West Azerbayjan province. Local name: Badame Gharabaghi
P. haussknechtii C. K. Schneid.	Thorny shrub with reddish and glaborous or some downy current shoots, previous year's shoots are glaborous and yellowish or gray–brown in color	Elliptical, large, hairy and flat fruits, 25–35 mm in length and 15–22 mm in diameter, almost boat-shaped shell with one shallow longitudinal groove	Endemic to Iran in the west and center of the country including Kurdistan, Kermanshah, Markazi, Lurestan, Isfahan, Fars, Kohgiluyeh–Boyerahmad and Chaharmahal–Bakhtiari provinces. Local name: Arjank or Badame Zagrosi
P. kurdistanica (Attar, Maroofi et Vafadar) Eisenman*	Shrub up to 2.5 m high, with sub-spiny glabrous branches, annual shoots brownish, old shoots brown gray	Fruit a drupe, elliptic ovoid, densely velutinous, acute, up to 28 mm long and 16 mm wide, uncompressed; stones bright brown, long elliptic ovoid, foveolate with some small grooves only near the base	Endemic to Iran from stony slopes of the Nakarouz mountain in Saqqez to Baneh (Kurdistan province), western Iran
P. elaeagnifolia Spach *	Shrub or small tree up to 3–4 m tall with glossy and yellow 1 year shoots,	Flat and oval fruit with yellow hair, up to 20 mm in length and 12 mm in diameter, brownish yellow kernel	Endemic to Iran, in the west and south of the country including Lurestan, Isfahan, Fars, Kerman, Kohgiluyeh–Boyerahmad and Chaharmahal–Bakhtyari provinces. Local name: Badame kermani or Barg Senjedi
(syn. *P. argentea* (Lam.) Rehder var. *elaeagnifoli*a Meikle)			
Subsp. *elaeagnifolia*	Hairy young shoot,	Fruit with short hair	
Subsp. *leiocarpa*	Glaborous young shoot	Glaborous fruit or with some scattered hair	

Table 1 continued

Species	Tree characteristics	Fruit properties	Distribution
P. runemarkii Eisenman (*A. reticulata* Runem. et Khat.)*	Thorny shrub up to 2 m tall, young shoots: glaborous, red color and later brownish gray in color	Oval-elliptical shaped fruit, flat and glaborous, up to 16 mm in length and 10 mm in diameter, shell: almost flat, brownish yellow, with deep grooves at base	Endemic to Iran in the south of the country in Fars (Bamou protected zone) province. Local name: Badame Moshabbak
*P. glauc*a (Browicz) A. E. Murray*	Simillar to *P. scoparia* except that trees are grayish blue in color and have elliptic leaves	Small elliptical fruits	Endemic to Iran in the south of the country in Fars (Kazeroon road) province. Local name: Badame Shirazi or Badame Kabud
P. scoparia (Spach) C. K. Schneid.	Thornless shrub up to 6 m tall, young shoot and annual shoot: glaborous and green in color	Hairy oval fruit, up to 20 mm in length and 12 mm in diameter, glossy and opaque yellow shell with shallow grooves	West, center, north east, south east, east and south of the country. Local name: Arjan or Badame kuhi
P. arabica (Oliv.) Meikle	Simillar to *P. scoparia*, except shoots are angular	Simillar to *P. scoparia*, but fruits with less hair and shell is brown	West and southwest of the country in Kurdistan, Kermanshah and Lurestan provinces. Local name: Badame Tavoosi or Vamchak
P. erioclada Bornm.	Thorny shrub up to 0.6 m tall, thorny. young shoot with white hairs, one year's shoots are blackish dark gray in color	Fruits covered with white hairs	South of the country including Fars (in Pasargad and Persepolis) and Lurestan provinces. Local name: Badame Persepolisi
P. × *iranshahrii* (Khat.) Eisenman*	Almost thorny shrub, current twigs with round cross section, thin and glaborous. Previous year's twigs are light brown in color	Oval-spherical fruits covered with yellow-gray hairs, soft and brown shell with round tip and diagonal base	Hybrid taxon. *P. scoparia* × *P. eburnea* Endemic to Iran, in south of the country in Fars province
P. eburnea Spach*	Thorny Shrub up to 1.5 m tall, gloosy young shoot with sharp tip and white or gray in color, 1 year's shoots are blackish dark grayish in color	Spherical-oval fruit, dark gray in color, hairy with yellow velvet hairs, up to 10 mm in length and 12 mm in diameter, shell with rough surface, small tip, and several small grooves at base	Endemic to Iran in the west, center, east, south and south east of the country including Kermanshah, Ilam, Tehran, Yazd, Isfahan, Fars, Khuzestan, Hormozgan, Sistan–Baluchistan and Khurasan provinces. Local name: Badame Ajee or Khakestary Badam
P. nairica (Fed. et Takht.) Eisenman	Shrub up to 1 m tall with sharp thorns, young shoot: glaborous and purple in color, one year's shoot is gloosy and white–gray in color	Elliptical or oval fruits, flat, round and rostral tip, covered with yellow velvet hairs, oval or oblong shell with grooves at base and reticulate lines at tip	North west of the country in the East Azerbayjan and Kurdistan provinces
P. spinosissima (Bunge) Franch. Subsp. *spinosissima* Subsp. *turcomanica* (Lincz.) Kitam. Var. *urumiensis* Bornm.*	Thorny small trees up to 2.5 m tall, young shoot is glaborous, glossy and red, cherry or reddish brown in color, one year's shoots are gray in color	Downy and red fruit: subsp. *spinosissima:* Oval and flat fruit with sharp tip, oval, flat with light brown shell which hardly is separated from the mesocarp. subsp. *turcomanica:* Spherical or oval spherical fruit with dull tip, spherical and dark brown shell which is easily separated from the mesocarp	North East of the country in Khurasan province Loacal names: Badame turcomanistani or Porkhar *Endemic to Iran, in northwest of the country in the West Azerbayjan province (Orumieh), local name: Badame Orumieh

Table 1 continued

Species	Tree characteristics	Fruit properties	Distribution
P. orazii (Maroofi, Attar et Vafadar) Eisenman*	Tree, 6 m high or more, with stricterect unarmed branches; annual shoots green brown, the oldest shoots dark gray, all branches glabrous	Fruit a drupe, ovoidelliptic, unilaterally curved, approximately acute, up to 34 mm long and 20 mm wide, uncompressed, densely velutinouspubescent; stones brown, ovoid, foveolate with small pores	Endemic to Iran, westhern Iran, Kurdistan province: Baneh, Nenor to Siranband village
P. orientalis (Mill.) Koehne	Thorny shrub up to 0.5–2 m tall, current twigs with white hair, while previous year's twigs are hrey in colour	Oval and almost bezel fruits, hairy fruit sometimes glaborous, 20 mm in length and 12 mm in diameter, shell smaller than fruit with very shallow grooves	West of Iran in Kurdistan, Kermanshah and Ilam provinces. Local name: Badame Shargi, Bekhourak
P. kotschyi (Boiss. et Hohen. ex Spach) Meikle	Shrub up to 0.5 m tall, almost thorny with downy current twigs that are glaborous and glossy, 1 year's twigs are brownish dark grey in color	Elliptical fruit covered with yellow hairs, almost glossy shell with some shallow grooves	West and northwest of the country in Kurdistan, Kermanshah, Lurestan, Markazi, Hamadan and West Azerbayjan provinces. Local name: Badame kurdistani
P. carduchorum (Bornm.) Meikle	Almost thorny shrub up to 0.5–1 m tall, thin and some downy young shoots, 1 year's shoot is greyish brown in color	Oval to round fruits with round tip, covered with short and grey hair, 10–15 mm in length and 10–12 mm in diameter, glossy shell	West and north west of Iran in East and West Azerbaijans, Kurdistan and Zanjan provinces. Local name: Chghalk
P. pabotii (Browicz) Eisenman*	Small and almost thorny tree, thorny young shoots with brown color, 1 year's twigs are grey in color	Elliptical and almost flat fruits, downy (short yellow) or glaborous fruits, 22 mm in length and 16 mm in diameter, oval and boat-shaped shell, 18 mm in length and has a small tip	West and north west of Iran, possibly hybrid of *P. haussknechtii* and *P. carduchorum*
P. brahuica (Boiss) Aitch. et Hemsl.	Thorny small tree with thin young shoots greyish white in color, previous year's twigs are thick and brown–grey in color	Round fruit covered with yellow hair, 15 mm in length and 12 mm in diameter, shell is diagonal at base with deep grooves	South east of Iran in Sistan–Baluchistan (mount Taftan) and Khorasan provinces. Local name: Badame Taftani or Badame Baluchistani
P. × *keredjensis* Browicz*	Almost thorny shrub, young shoots are glaborous, thin, and green in color, previous year'stwigs are grey in color	Spherical or oval-spherical fruits, without pedicle, 10 mm in length and diameter, glossy and almost flat shell with shallow grooves at the base	Hybrid taxon. *P. scoparia* × *P. lycioides* Endemic to Iran in the center of the country in Tehran and Alborz provinces
P. × *podoperae* (Woron.) Náb. *	Small tree up to 1.5 m tall with thin and thorny shoot, current twigs are glaborous while some are downy with green or yellowish green color	Unknown	Hybrid taxon. *P. scoparia* × *P. elaegnifolia* subsp. *leiocarpa* Endemic to Iran in the south. Local name: Badame Khormuji
P. × *mozaffarianii* (Khat.) Eisenman*	Almost thorny shrub, current twigs with round cross section, thin, downy and green in color. Previous year's twigs are greyish brown in color	Spherical, asymmetric, covered with yellow–grey hair, 15 mm in length and 12 in diameter, brown shell with dull tip and diagonal base, shell with deep grooves at the base and reticulate lines on the tip	Hybrid taxon. *P. scoparia* × *P. brahuica.* Endemic to Iran, in the south east in Baluchistan (mount Taftan) province

Table 1 continued

Species	Tree characteristics	Fruit properties	Distribution
P. × *yasujensis* (Khat.) Eisenman*	Almost thorny shrub, current twigs have downy, thin, round cross sections and are green in color	Unknown	Hybrid taxon. *P. scoparia* × *P. elaegnifolia* subsp. *elaegnifolia* Endemic to Iran and found in Yasouj (Sisakht) town
P. × *kamiaranensis* (Khat. et Assadi) Eisenman*	Small tree up to 2 m tall, partly thorny, current twigs are glaborous and have thin, round cross sections that are green in color. Previous year's twigs are light brown in color	Downy oval fruit, 18–20 mm in length and 12–15 in diameter, with dull or oblong tip, shell is partly boat shaped and soft with shallow grooves at the base	Hybrid taxon. *P. scoparia* × *P. haussknechtii.* Endemic to Iran in the west in Kurdistan (Kamiaran road) province
P. lycioides (Spach) C. K. Schneid. Var. *lyciodes* Var. *horrida* (Spach) C. K. Schneid.*	Thorny shrub up to 1 m tall, glaborous and brownish young shoots and white–grey one year old shoots	Oval or wide-ovate and velvet downy fruit, Var. *lyciodes*: up to 15 mm in length and 12 mm in diameter, bezel fruit, thin boat shaped shell with deep longitudinal groove and several reticulate grooves * Var. *horrida*: almost outstanding fruits, small in size, wide boat shaped shell with small longitudinal grooves	Var. *lyciodes:* North, west, south and center of the country in Mazandaran, Gilan, Azerbaijan, Tehran, Kurdistan, Kermanshah And Semnan provinces * Var.*horrida*: endemic to Iran, in the center and south in Isfahan, Fars, Kerman, Tehran, Hormozgan and Semnan provinces. Local name: Badame Khardar, Tangras

* Endemic to Iran

characteristics including late bloom [*P. carduchorum* (Bornm.) Meikle, *P. elaeagnifolia* Spach, *P. kotschyi* (Boiss. et Hohen.) Meikle, *P. glauca* Browicz or *P. scoparia* (Spach) C. K. Schneid.], early maturity [*P. spinosissima* (Bunge) Franch. var. *urumiensis* Bornm.], compact growth habit [*P. fenzliana* Fritsch, *P. orientalis* (Mill.) Koehne or *P. scoparia* (Spach) C. K. Schneid.], resistance to drought (wild almond species with very small leaves especially in the Spartioides section including *P. scoparia*), salinity, adaption to low winter temperatures and reduced insect infestation and fungal attack. However, species in the Spartioides section with hard shells and well-sealed sutures have not been sufficiently exploited (Sorkheh et al. 2009b; Gradziel and Martínez-Gómez 2002; Gharaghani and Eshghi 2015; Baninasab and Rahemi 2007). On the other hand, the germplasm of wild species in Iran is not a useful source for selection of larger nut and kernel size with the possible exception of *P. korshinskyi* Hand-Mazz. and *P. communis* L. However, for local production, some of the wild accessions possessed relatively large kernel weight that were similar or exceeded the kernel weights of local commercial cultivars (Sorkheh et al. 2009b).

Using wild almond species as rootstock in Iran date back to about 300 years (Madani et al. 2006). The seedlings of *P. scoparia* (Spach) C. K. Schneid., growing wild in Iran have been used by growers in very arid conditions for top-working almond cultivars (Gentry 1956). More than 5000 ha of almond cultivars grafted on wild rootstocks have been reported in Fars, Kerman, Boushehr and Hormozgan provinces. *Prunus scoparia* (Spach) C. K. Schneid., is one of the main species that have been used as a rootstock for almond in non-irrigated conditions (Rahemi and Yadollahi 2006). In addition, *P. scoparia* (Spach) C. K. Schneid., *P. elaeagnifolia* Spach, and *P. eburnea* Spach, naturally distributed in many regions of Iran, have been used in arid and semi-arid areas to control soil erosion and as water sheds (Madam et al. 2011) and their products are used locally. For example, the kernel of *P. scoparia* (Spach) C. K. Schneid., is used as an edible nut after de-bittering and roasting (Gholami et al. 2010; Gharaghani and Eshghi 2015). In Iranian traditional folk medicine, the kernel oil of *P. scoparia* has been used to treat cancer (especially of the bladder, breast, mouth, spleen, and uterus), asthma, kidney stone, spasm, bronchitis and heart disease (Gharaghani and Eshghi 2015). *Prunus elaeagnifolia* Spach, is also used as a rootstock for plum (Gholami et al. 2010).

Table 2 Phenological and pomological characteristics of indigenous almond cultivars of Iran

Cultivar	Phenological and pomological traits
'Azar'	Old cultivar (obtained from crossing programs), late flowering, ease of harvest (suitable for mechanical harvesting), high productivity, does not have bi-annual bearing, percentage of kernel to fruit ~40 to 42%, percentage of double kernel very low (0–2%), high tolerance to foamy canker, self in-compatible. Pollenizer cultivar: 'Ferragnès'
'Shekofeh'	Old cultivar (obtained from crossing programs), very late flowering, percentage of kernel to fruit is 55–60%, percentage of double kernel ~2%, harvesting is a little difficult, some bi-annual bearing, sensitive to foamy canker. Self in-compatible. Pollenizer cultivars: 'Ferragnès', 'Harir'
'Harir'	Old cultivar (obtained from crossing programs), late blooming, paper shell, percentage of kernel to fruit is 55%, 0% double kernel, self in-compatible. Pollenizer cultivars: 'Ne Plus Ultra', 'Nonpareil'
'Sahand'	Old cultivar, late flowering, does not have bi-annual bearing, with low percentage of kernel to fruit ratio (~25 to 28%), high percentage of double kernel (~15 to 20%), very high productivity, self in-compatible. pollenizer cultivars: 'Ferragnès', 'Shekofe'
'Eskandari'	New cultivar (obtained from crossing programs), late flowering, early ripening, ease of harvest is average, easy peeling, 2–4% double kernel, with 48–49% kernel: fruit ratio, high productivity, self in-compatible. Pollen donor cultivars: 'Azar', 'Araz' and 'Yalda'
'Araz'	New cultivar (obtained from crossing programs), late flowering, very early ripening, ease of harvest, easy peeling (husk removal), no double and twin kernel, high percentage of kernel: fruit ratio (~59 to 60%), moderate productivity, self in-compatible, Pollenizer cultivars: 'Yalda' and 'Eskandar'
'Saba'	New cultivar (obtained from crossing programs), late flowering, mid-ripening, very thin shell, 0–5% twin kernel, with 55–60% kernel: fruit ratio, ~1.7 t/ha productivity, self in-compatible. Pollenizer cultivars: 'Azar' and 'Supernova'
'Aidin'	New cultivar (obtained from crossing programs), late flowering, mid-ripening, with hard or stony shell, 0–5% twin kernel, 32–40% kernel: fruit ratio, ~2.6 t/ha productivity, self in-compatible, Pollenizer cultivar: 'Shahrood 12' ('Ferragnes')
'Monagga'	Very early flowering, fruit is thin shelled, 50–55% kernel: fruit ratio It is usually damaged by spring frost in Azerbayjan province, self in-compatible. Pollenizer cultivars: 'Rabie', 'Sefid'
'Mamaei'	An indigenous cultivar, mid-blooming, fruits with hard shell, 48% twin kernel, percentage of kernel to fruit is around 36%, self-incompatible. Pollinizer cultivars: 'Rabie', 'Sefid'
'Sefid' ('Mohebali')	An indigenous cultivar, early to mid-bloom, paper shell, 20% twin kernel, ~54% kernel: fruit ratio, self in-compatible
'Rabie'	An indigenous cultivar, early blooming, fruit with hard shell, 56% twin kernel, percentage of 33% kernel: fruit ratio, self in-compatible. Pollenizer cultivar: 'Mamaei'

In recent years, many studies have been conducted to unravel the morphological and molecular diversity of Iranian genotypes, cultivars and wild species of almond. Molecular markers such as amplified fragment length polymorphism (AFLPs) (Sorkheh et al. 2007, 2009a; Zeinalabedini et al. 2014), SSRs (Shiran et al. 2007; Fathi et al. 2008a; Sorkheh et al. 2009a; Zeinalabedini et al. 2010, 2014; Kadkhodaei et al. 2011; Zamani et al. 2009a; Rahemi et al. 2012; Mehdigholi et al. 2013; Rasouli et al. 2014a), and random amplified polymorphic DNAs (RAPDs) (Shiran et al. 2007; Sorkheh et al. 2009a; Nikoumanesh et al. 2011; Rasouli et al. 2012), have been used in addition to cytogenetical analysis (Rasouli et al. 2014b; Yousefzadeh et al. 2010) and morphological analysis (Fathi et al. 2008a; Sorkheh et al. 2009b; Kadkhodaei et al. 2011; Zamani et al. 2009a; Rahemi et al. 2011; Ardjmand et al. 2014). As a whole, the results of these studies demonstrate considerable genetic diversity in the Iranian almond germplasm both at morphological and molecular levels indicating a rich and valuable gene pool for almond rootstock improvement. Also, molecular markers (especially SSR markers) could be successfully used to determine the genetic diversity among Iranian almond landraces/cultivars and to also identify informative markers for improving traits in breeding programs. In addition, based on molecular dendrograms, groupings of different almond cultivars have been identified based on geographic origin and some morphological traits.

Considerable genetic variation exists in nut traits within and between populations of *P. scoparia* (six populations from different regions of Fars province and one population from the Chaharmahal–Bakhtiari province), *P. dulcis*, *P. eburnea*, and *P. elaeagnifolia* (Rahimi Dvin et al. 2016; Ansari and Gharaghani 2016). They showed that cluster analysis divided wild populations into four sub clusters based on geographic proximity and species. Also, Khadivi-Khub and Anjam (2014) studied morphological characterization (21variables of tree, leaf and fruit traits along with flowering and ripening date) of 150 wild accessions of *P. scoparia* species from four regions of Iran including Estahban, Arak, Sardasht and Mehalat. They reported that all the characteristics examined showed a high degree of variation although this was pronounced for secondary shoot number, leaf area and shape, growth habit, fruit exocarp color, nut shape, pubescence on fruit, canopy size and trunk diameter (Khadivi-Khub and Anjam 2014). As a whole, the phenotypic variability in Iranian wild *P. scoparia* species is very high, suggesting an extensive genetic diversity of genetic resources available for use in the almond cultivar and rootstock development programs. The wide adaptation of this species highlights its potential as genetic resource for breeding for resistance to abiotic and biotic stresses such as drought and spring frost.

Cytological studies of four wild almond species including *P. elaeagnifolia* Spach, *P. erioclada* Bornm., *P. eburnea* Spach, and *P. scoparia* separated them into 2A (*P. elaeagnifolia* Spach and *P. erioclada* Bornm.) and 2B (*P. eburnea* Spach and *P. scoparia* Spach) karyotypic symmetry classes (Yousefzadeh et al. 2010). Shiran et al. (2007) grouped almond cultivars with accessions of *P. dulcis* indicating a very close relationship, whereas, *P. orientalis* and *P. scoparia* clustered together and separately from the rest of *P. dulcis*. Zeinalabedini et al. (2010) showed that *P. fenzliana* had the closest genetic relationship with cultivated almonds, suggesting that *P. fenzliana* may be the most plausible progenitor of cultivated almonds. Zeinalabedini et al. (2008) and Sorkheh et al. (2009b) suggested that the presence of undesirable fruit and kernel traits such as self-incompatibility, bitter kernel taste and small fruit size limits the use of wild almond species for transferring useful properties into cultivated almonds and concluded that wild *Prunus* species are less useful in almond cultivar improvement. In contrast, Nikoumanesh et al. (2011) reported that the wild plant materials used in the previous studies above provide valuable sources for rootstock genetic improvement programs in arid and semi-arid regions.

Fertilization is essential for almond commercial production although most almond cultivars are self-incompatible (Socias i Company 1990). Self-incompatibility in almond is gametophytic and controlled by a single *S*-locus with multiple codominant alleles (Dicenta and Garcia 1993). The identity of *S*-alleles is important for designing crosses and choosing parents for breeding self-compatible cultivars which are suitable for monoculture orchards with reduced need for honeybee pollinators (Batlle et al. 1997). Many studies have been carried out to identify incompatibility alleles of Iranian almond cultivars and wild species mainly based on polymerase chain reaction (PCR) (Valizadeh and Ershadi 2009; Rahemi et al. 2010; Sheikh-Alian et al. 2010; Mousavi et al. 2011; Momenpour et al. 2011; Zeinalabedini et al. 2012; Hafizi et al. 2013; Rahemi et al. 2013; Mousavi et al. 2014). Results showed that Iranian almond cultivars are valuable sources of new almond self-incompatibility and self-compatibility alleles and good agronomic traits, all of which are of interest in almond breeding and conservation programs. Mousavi et al. (2014) studied the diversity of self-incompatibility alleles in Iranian cultivars and introduced 8 new alleles (S_{36}–S_{43}) including 'Tejari' (S_{36}), 'Holouei' (S_{37}), 'Sefid' (S_{38}), 'Yazd-17' (S_{39} and S_{40}), 'Mashhad 40' (S_{41}), 'G-R-16' (S_{42}) and 'Mamaei' (S_{43}). They also reported that one of the alleles (S_{40}) was similar to S_5 which was identified previously in an accession of the wild species, *P. webbii* (Spach) Vierh. This finding points to the existence of a common ancestor with other *Prunus* species and also suggests a possible introgression from *P. webbii* (Spach) Vierh., a primary ancestor in almond evolution. Similarly, Hafizi et al. (2013) identified 6 new *S*-RNase alleles (S_{45}–S_{50}) in local cultivars including 'Sher badam' (S_{45}), 'Haji badam' (S_{46}), 'Mamaei' (S_{47}), 'Sefied' (S_{48}), 'Shekofeh' (S_{49}) and 'Shahrodi-1' (S_{50}). They also showed that some cultivars like 'Azar' ($S_{24}S_{na}$), 'Shekofeh' ($S_{49}S_{?}$) and 'Shahrodi-1' ($S_{50}S_{?}$) displaying one non-functional *S*-RNase would be of interest in almond breeding programs as resources for new almond self-compatibility alleles. Based on the above-mentioned results it appears that the cultivars with new *S* alleles may be useful as suitable parents in almond breeding programs to ensure the success of controlled crosses.

Initial assessments of tolerance of some native cultivars, genotypes and wild species of almond to abiotic stresses have been conducted under in vitro or in vivo conditions. Further studies undertaken to validate the performance of highly tolerant cultivars identified in previous research showed variations in response to water stress presumably due to the rich genetic resources of wild almonds in Iran. This suggests the possibility of using them in breeding programs. It may appear that *P. scoparia* Spach (Madam et al. 2011; Gholami et al. 2010), *P. eburnea* Spach (Zokaee-Khosroshahi et al. 2014), *P. arabica* (Oliv.) Meikle, *P. glauca* Browicz and *P. scoparia* Spach (in the Spartioides section) (Sorkheh et al. 2011a), and the local cultivar 'Sefid' (Yadollahi et al. 2011) could be useful under drought conditions. Among the Iranian cultivars, 'Shekofeh' (grafted on 'GF677', will tolerate salinity of 7.3 ds/m and partly salinity of 9.8 ds/m) (Momenpour et al. 2015), 'Araz' and 'Eskandar' (Bybordi 2013) have been identified as salinity tolerant at a base concentration of nutritional elements and their ratios. On the other hand, 'Sahand' (grafted on 'GF677') is believed to be the most sensitive to salinity stress (Momenpour et al. 2015). The effect of temperature (between 5 and 50 °C, at 5 °C intervals) on pollen germination and pollen tube growth of native Iranian almonds species was studied (Sorkheh et al. 2011b) under in vitro conditions to identify differences in the tolerance of pollen to temperature variations. The species in the section Lycioides (*P. lycioides* (Spach) C. K. Schneid., *P. reuteri* Boiss. et Buhse) and *P. communis* L. were the most heat-tolerant species, those in the section Euamygdalus (*P. elaeagnifolia* Spach, *P. orientalis* (Mill.) Koehne) were intermediate, while those in the section Spartioidies (*P. arabica* (Oliv.) Meikle, *P. glauca* Browicz, *P. scoparia* Spach) were the most heat-susceptible.

Cherry

In Iran, sweet cherry (*P. avium* L.), sour cherry (*P. cerasus* L.) and mahaleb (*P. mahaleb* L.) (Fig. 3) are called Gilas, Albaloo and mahleb, respectively. Based on the latest available statistics of FAOSTAT (2016), Iran with 200,000 t production and 29, 000 ha of harvestable area is the 3rd largest producer of sweet cherry in the world after Turkey and USA. Also, Iran with 106,972 t production from 12,000 ha of harvestable area ranks 6th in the world in sour cherry production. The major commercial cherry orchards in Iran are in Tehran, Alborz, Khorassan-Reazavi, Isfahan, Ghazvin and West Azerbayjan provinces (Ministry of Agriculture 2014). The two main species, sweet and sour cherries, are reported to have originated from an area between the Black and Caspian seas including Asia Minor, Iran, Iraq, and Syria, from where they spread gradually to other areas due to human and animal migration (Zamani et al. 2012). The mahaleb cherry is native to Mediterranean, Southeast Europe and West Asia, although it is sometimes also found in Central Europe (Buman 1977).

Wild and domesticated genetic resources

Iran represents a significant source of germplasm for different fruit species in the Cerasus subgenus including 13 species of which *P. chorassanica* (Pojark.) A. E. Murray, *P. microcarpa* (Boiss.) C. A. Mey. subsp. *diffusa* (Browicz) Schneid. (Sabeti 1997; Khatamsaz 1992), *P. yazdiana* Mozaff. (Mozaffarian 2005) and *P. paradoxa* Dehshiri et Mozaff. (Dehshiri et al. 2012) are endemic to Iran (Table 3). The Most important native cultivars of sweet cherry in Iran are 'Siah Mashhad', 'Tak daneh', 'Siah Shabestar', 'Zarde Daneshkadeh', 'Soraty Lavasan', 'Ghermeze Rezaeyeh', 'Haj Yousefy', 'Pishrase Mashhad' (early season), 'Dovomras Mashhad', 'Siah Ghazvin' and two new cultivars, 'Sefide 90' and 'Zarde 90' (released in 2011). All genetic resources of sweet cherry in Iran are self-incompatible and mid-season excluding 'Sefide 90' which is self-compatible and late-season with high production (i.e., 20% more production). 'Sefid-90' was released in Karaj research station and has many useful traits including dwarfing, suitability for processing (canned industry, jam, etc.), ease of transportation, waste reduction and resistance to fungal diseases (Seed and plant improvement institute 2016). Also, 14 years of research (from 1998 to 2012) at the Khorasan-e Razavi agricultural and natural resource research center and Karaj horticultural research station resulted in the introduction of a new cultivar 'Adli' from the selection program of local germplasm from Khorasan province. 'Adli' is very early cultivar (a week earlier than foreign early cultivar 'Blamarka') and is resistant to fruit twining

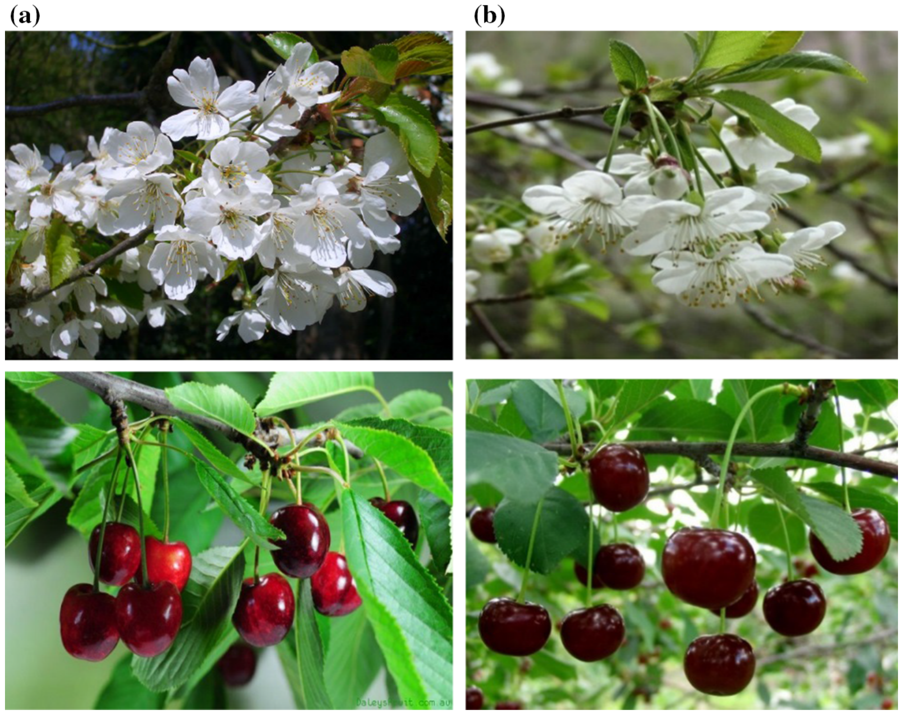

Fig. 3 **a** Flower and fruit of sweet cherry (*P. avium* L.), and **b** sour cherry (*P. cerasus* L.)

and cracking, and has marketable fruit with big size (Khorasan-Razavi Agricultural and Natural Resources Research Center 2016). Wild genotypes and local cultivars are likely gene sources to achieve breeding objectives such as resistance to pests and diseases, suitability for table and processing, extending the market season, and developing new resistant and dwarfing rootstocks. Therefore, it is necessary to characterize and preserve these genotypes and cultivars (Demirsoy and Demirsoy 2004). The first published work on collection of cherry germplasm including 39 indigenous and imported cultivars was by Gohar Khai (1987). This collection was reclaimed at 1998 by adding 70 genotypes and imported cultivars (Abdollahi et al. 2010). Also, Khorasan germplam including 50 genotypes and local cultivars was collected and reclaimed by Ganji Moghadam which resulted in the protection of the mutants of the local cultivar 'Siah mashhad' (Ghanji Moghadam 2004). In the case of sour cherry germplam, Bouzari et al. (2009a) collected more than 250 genotypes and 5 important species from 12 provinces in Iran. Today, there are 160 accessions of sweet cherry and 180 accessions of sour cherry at the Kamal-shahr station in Karaj and other affiliated provincial stations (Abdollahi et al. 2010).

Evaluation and use of genetic resources

In Iran, sweet cherry is valuable due to its edible fruit (with good taste), short ripening period, and eraly blooming in the spring (Ganji Moghadam et al. 2013). Sour cherry is also cultivated for its sharp taste and juicy fruits, mostly for industrial preserves. Sour cherry is also used as rootstock for sweet cherry. Other types of use for sour cherry specific to Iran include; 'Albaloo Akhteh' (a de-pited, semi-dried and salted form of sour cherry which is used in special dishes) and 'Chay Albaloo' (sour cherry fruit tea common in Ardebil and other parts of Iran). Sour cherry is also used for cooking, and in making jams and syrups in Iran.

Some species in the Cerasus subgenus are used for landscaping, and also as rootstocks for sweet and sour cherries. In addition, these species are used in breeding programs for developing new commercial cultivars as well as dwarfing and resistant rootstocks (Iezzoni 2008). For example, Mahaleb cherry (*P. mahaleb* L.)

Table 3 Tree and fruit characteristics and distribution of cherry species in Iran. Adapted from Khatamsaz (1992), Mozaffarian (2005)

Species	Tree characteristics	Fruit properties	Distribution
P. brachypetala (Boiss.) Walp. Var. *brachypetala* Var. *bornmülleri* Schneid.	Small wide-spreading shrubs, with dense and short branches, current and one year old shoots with delicate hairs, older shoots brown–gray in color	Drupe: red, spherical–oval, up to 8 mm in diameter, with acute apex, unripe drupe almost downy then became glaborous, ripe drupe downy at apex, striate endocarp with some suture	West, south and center of Iran in: Hamadan, Isfahan, Fars, Kohgiluyeh–Boyerahmad and Chaharmahal–Bakhtyari provinces Hamadan and Chaharmahal–Bakhtyari provinces
P. incana (Pall.) Batsch	Erect shrub, up to 2 m tall, with thin, erect and long branches, young shoots with white hair then become glaborous and gray	Drupe: almost spherical, dark red, 6–7 mm in diameter, with acute or dull apex, reticular endocarp with some furrows	Northwest of Iran in East and West Azerbayjans and Kurdistan provinces. Local name: Marmareh or Albaloo koohi
P. araxina Pojark. Var. *araxina* [syn: *P. albicaulis* Koehne et Bornm.] Var. *sintenisii* (Browicz) Schneid. [syn: *P. incana* (Pall.) Batsch var. *sintenisii* Schneid.]	Erect shrubs, up to 2 m tall, with downy and green young shoots	Drupe broad ovoid, red, 8–10 mm in diameter, with reticular-striate endocarp	North west of Iran in East and West Azerbayjan provinces
P. pseudoprostrata (Pojark.) Rech.f.	Shrubs with a dense complex of branches downy then gradually become glaborous, one year old shoots gray–yellow in color, older shoots is gray	Drupe oval–spherical, up to 9 mm long, with acute apex, unripe drupe downy, reticular endocarp with shallow furrows	Northeast and north of Iran in Golestan, Mzandaran, Khorasan and Tehran provinces
P. chorassanica (Pojark.) A. E. Murray *	Small shrub, with dense branches, twigs with a lot of gray hairs	Drupe ovoid, red, downy, 8 mm in length, 6 mm in diameter, endocarp ovoid, with acute apex, 6 mm long, 5 mm in diameter, reticular-striate	Endemic to Iran in the northeast including Khorasan (Hezar Masjed mountains) province. Local name: Albaloo Khorasani
P. microcarpa (Boiss.) C. A. Mey. Subsp. *tortuosa* Subsp. *microcarpa* Subsp. *diffusa* (Browicz) Schneid.*	Erect or wide-spreading shrubs, up to 3 m high, without thorn or sometimes with thorny small shoots, brown or gray–brown shoots	Drupe ovoid, sometimes spherical, with acute apex, 8–10 mm in length, glaborous, black, red, and yellow in color, glossy endocarp with shallow grooves	Subsp. *diffusa* is endemic to Iran, including Isfahan, Mazandaran, Fars, Lurestan, and Kermanshah provinces. Also other subspecies are found in Golestan, Giulan, Markazi, Kurdestan, Tehran, and Khorasan provinces Local name: Ranas
P. avium L.	Trees up to 25–35 m tall, older trunk almost black, young shoots glaborous and green, older shoots brown–red and bright.	Drupe almost spherical, 1–1.5 cm in diameter, red, black, yellow, white, bright, sweet, sour or bitter, endocarp ovoid or spherical and glossy	In the north of Iran in Mazandaran, Giulan and Azerbaijans are found as wild trees, also cultivated in many other provinces. Local name: Gilas or Alookak
P. cerasus L.	Small trees up to 10 m tall, sometimes produce suckers, with large divergent crown, young shoots glaborous, green and later brown–red	Drupe spherical, light red, 15 mm in diameter, with red or black flesh, sour or some sweet taste, endocarp spherical, glossy and seed strongly attached to endocarp	This species is cultivated in many regions of Iran. Local name: Albaloo

Table 3 continued

Species	Tree characteristics	Fruit properties	Distribution
P. mahaleb L.	Shrubs up to 2–10 m (rarely 15 m) in height, older trunk with almost black bark, younger trunk thin, glaborous or short hair, shoots green and later brown	Drupe ovoid, 7–12 mm in length, 6–10 mm in diameter, yellow then red and finally black, sour or bitter, endocarp ovoid, 8 mm long, 5 mm wide, glossy	Mainly in the west and north west of Iran in Azerbayjans, Kuristan, Lurestan, Hamadan, Yazd and Chaharmahal–Bakhtiari provinces
P. turcomanica (Pojark.) Gilli	Small shrubs with dense and divergent branches, young shoots short, thin, downy; older shoots glaborous, grey–brown and later turn grey and striate	Drupe almost spherical, 8–9 mm in diameter, red, ripe drupe glaborous, endocarp reticular with shallow grooves	Northeast of the Iran in Golestan province. Local name: Albaloo turcamanestani
P. yazdiana Mozaff.*	Erect shrub, up to 2 m high, with erect or curved, long and thin branches, young shoots grey or purple and glaborous	Drupe elliptical shaped, glaborous, 6–8 mm long, 4–6 mm wide, dark red, and sweet. Endocarp: oval, 5 × 8 mm dimension, reticular–wizened	Endemic to Iran in the center of the country in Yazd province (Mehriz). Local name: Albaloo yazdi
P. paradoxa Dehshiri et Mozaff.*	Erect shrub up to 2–3 m high, with erect or more or less spreading branches, young shoots erect, thin, long, glaborous, greyish, older shoots dark grey to blackish-grey	Ripe drupe sub globose, 8–10 mm diam., red, glabrous, endocarp ovoid, with acute apex, 7–9 mm long, 3–5 mm wide, smooth on both sides, with sparse network of shallow furrows confined to apex and vicinity sutures	Endemic to Iran, in the west of the country in Lurestan province

* Endemic to Iran

is tolerant to lime-induced iron chlorosis and zinc deficiency and is currently used as sweet cherry rootstock in light and calcareous soils, as well as, in arid climates in Iran (Ganji Moghadam and Khalighi 2007). *P. microcarpa* (Boiss.) C. A. Mey., *P. brachypetala* (Boiss.) Walp., *P. pseudoprostrata* (Pojark.) Rech.f., and *P. incana* (Pall.) Batsch are shrubs with mostly recumbent habit. *P. mahaleb* L. and *P. cerasus* L. have spreading to erect habit and medium-sized trees, while most *P. avium* L. genotypes have large erect trees. These species may be useful as gene sources for cherry breeding programs (Shahi-Gharahlar et al. 2010). Breeding goals for sweet and sour cherries are dependent on many factors such as environment, biotic factors, and economic conditions, although the main breeding targets are high yield, resistance to diseases, suitability for mechanical harvesting and processing, precocity, tolerance to frost and freeze damage, self-compatible pollination, round pits, firm, large, and good shipping-quality fruit with resistance to cracking and pitting, early to late ripening, reduced double fruiting, dwarfing rootstocks adapted to different soils, and low suckering (Iezzoni 2008; Shahi-Gharahlar et al. 2010; Zamani et al. 2012).

Genetic variation in Iranian *Cerasus* subgenus species and genotypes has been studied based on molecular markers including RAPDs (Khadivi-Khub et al. 2008; Zamani et al. 2009b; Zamani et al. 2009c; Zamani et al. 2012; Homayouni et al. 2012; Gharooni et al. 2012), SSRs (Najafzadeh et al. 2013a; Khadivi-Khub et al. 2014; Farsad and Esna-Ashari 2016), inter simple sequence repeat (ISSR) (Najafzadeh et al. 2013b), sequence-related amplified polymorphism (SRAP) (Abedian et al. 2012), protein markers (Bouzari et al. 2006) and morphological markers (Ganji-Moghadam et al. 2006; Ganji Moghadam and Khalighi 2006; Khadivi-Khub et al. 2008; Shahi-Gharahlar et al. 2010; Zamani et al. 2012; Homayouni et al. 2012; Gharooni et al. 2012; Ganji Moghadam et al. 2013; Farsad and Esna-Ashari 2016) or pomological characteristics (Ahmadi Moghadam et al. 2012; Najafzadeh et al. 2014). Results showed considerable genetic diversity at both morphological and molecular levels, indicating that there is a pool of valuable plant material for future cherry scion and rootstock breeding programs. Conclusions from ongoing studies suggest that a combination of molecular and morphological data provides the best data for identifying informative markers. Similarly, all molecular marker platforms can be successfully used to dissect genetic diversity among Iranian cherry landraces/cultivars and identify informative markers for the breeding of important traits. Studies have also shown that divergence among accessions occurred via genetic diversity of species and genotypes in the Cerasus subgenus according to genetic base and origins. These divergent genotypes should provide useful resources for breeders interested in improving sweet and sour cherry cultivars and rootstocks for special traits. Moreover, Khadivi-Khub et al. (2008) and Zamani et al. (2009b) showed that RAPD markers can be successfully used to study incompatibility for sweet cherry pollination. Results by Khadivi-Khub et al. (2014) study confirmed that nuclear SSR (nuSSR) marker data can be used for taxonomic purposes in the *Prunus* (subgenus Cerasus). The authors also reported that Chloroplast SSR (cpSSR) markers clearly differentiated between *P. avium* and *P. cerasus* and also confirmed that the chloroplast genome of *P. cerasus* L. was not derived from *P. avium* L. This provides support for the assertion that *P. avium* L. is not the maternal parent of *P. cerasus* L. The authors also observed some cases of similarity between nuSSR and cpSSR data sets. For example, both subspecies of *P. microcarpa* (Boiss.) C. A. Mey. showed similarity to *P. avium* L. In addition, *P. brachypetala* (Boiss.) Walp., *P. incana* (Pall.) Batsch, *P. pseudoprostrata* (Pojark.) Rech.f. and *P. yazdiana* Mozaff. showed interspecific similarity with each other and were placed in the same cluster. Also, this was true in the case of *P. mahaleb* L. that was separated from other species based on the two data sets. In contrast, *P. avium* L. and *P. cerasus* L. showed high interspecific similarity using nuSSR data but not with cpSSR data (Khadivi-Khub et al. 2014).

Homayouni et al. (2012) studied Iranian sour cherry genotypes from 10 provinces using morphological and molecular markers (RAPD) and reported that sour cherry has more genetic diversity in the north west of Iran (in the west of Azerbayjan province) indicating more genetic distance by moving toward the center of diversity.

Shahi-Gharahlar et al. (2010) evaluated 74 accessions of the Cerasus subgenus in Iran based on vegetative characters and reported that genotypes of *P. microcarpa* (Boiss.) C. A. Mey., *P. pseudoprostrata* (Pojark.) Rech.f. and *P. brachypetala* (Boiss.) Walp., produced shrubs of short stature with recumbent vegetative habits, low leaf area and high pubescence on the leaf upper and lower surface. These species may appear suitable for breeding, especially for developing dwarfing rootstocks with resistance to drought and cold tolerance. Also, cluster analysis (Ward method) based on seven factors classified the genotypes into two main groups (Microcerasus and Eucerasus). Triplot analysis using three factors also confirmed the location of genotypes and differentiated the species from each other.

According to vegetative traits, Ganji Moghadam and Khalighi (2007) classified different mahaleb (*P. mahaleb* L.) genotypes (17 autochthonous populations of mahaleb) into several groups. The authors showed that mahaleb genotypes had a lot of variation in vigor. Also, autochthonous Kurdistan-1 (K-1) and Khorasan-7 (KH-7) populations had the lowest and highest heights, width and crown volume, respectively.

Evaluation of pomological and morphological variation in some selected sour cherry genotypes showed that Iranian sour cherry genotypes were superior in terms of properties such as high vigor, yield, fruit weight, total soluble solids (TSS), high firmness, total acidity (TA), panel test results and redness than foreign cultivars (Najafzadeh et al. 2014).

Self-icompatibility in sweet cherry (*P. avium* L.) is one of the main challenges in commercial cherry orchards in Iran and many other countries, and plays an important role in yield reduction. Most cherry cultivars need a pollinizer cultivar to encourage pollination (Tehrani and Browns 1992). In addition to self-incompatibility, cherry cultivars also show incompatibility toward each other (cross incompatibility). Therefore, identification of compatible and incompatible groups is of great importance for the establishment of cherry orchards (Roger 1986).

The development of self-compatible cultivars has become a primary goal of many breeders. With a few exceptions, self-compatible genotypes usually guarantee steady and higher yields, as well as ease of adaptation to a wider range of environmental conditions, than self-incompatible genotypes (Stanys et al. 2008). They can also be used as universal pollinators when planted with the latter genotypes (Sansavini and Lugli 2005). With the exception of 'Sefid-90', all Iranian sweet cherry cultivars are self-incompatible. Self and cross-(in) compatibility in Iranian cultivars of sweet cherry have traditionally been determined by monitoring the fruit set percentage under field conditions (Arzani et al. 1992; Ganji Moghadam et al. 2009; Rasouli et al. 2010; Ahmadi Moghadam et al. 2012; Imani et al. 2013), and by observation of pollen-tube growth in the pistil using fluorescence microscopy (Asghari, 2003; Mahmoudi et al. 2007; Rasouli and Arzani 2010; Imani et al. 2013). Modern methods of identification of *S*-alleles in local cultivars of sweet cherry have also been investigated based on Allele-Specific PCR amplification (Hasani Moghadam 2006; Ershadi and Moghadam 2009). Other studies based on RAPD markers have shown that the grouping of some cultivars was correlated with the incompatibility system of pollination of sweet cherry (Khadivi-Khub et al. 2008; Zamani et al. 2009c). The *S*-genotypes of 25 Iranian and foreign sweet cherry cultivars were studied using classical PCR (Ershadi and Moghadam 2009) and the results showed that only S_3, S_4, and S_{14} alleles were detected in Iranian sweet cherry cultivars. S_3S_4 was the most frequent cross incompatibility group (CIG) observed in 36% of Iranian sweet cherry cultivars. Moreover, one new CIG was proposed with S_4S_{14} genotype including 'Sorati hamadan', 'Binam', and 'Siah gazvin' cultivars.

Plant tissue culture is an important tool in both basic and applied studies as well as in commercial application. In Iran, the use of in vitro propagation of some cherry and mahaleb dwarf genotypes has been reported (Izadpanah 2001; Amiri 2007; Ganji Moghadam 2011; Daneshvar Hosseini et al. 2011). Amiri (2007) reported micrografting with the homoplastic apex graft (shoot-tip), with apical bud scion length greater than 6 mm having a good potential for mass propagation of disease-free sweet cherry. Also, the findings of Daneshvar Hosseini et al. (2011) showed that mahaleb rootstock can be propagated using an in vitro method. It appears that Murashig and Skoog (MS) media including 6-benzylaminopurine (BAP), indole-3-butyric acid (IBA) growth regulators may be the most suitable for micro propagation.

The diseases that breeders mostly emphasize include brown rot (*Monilinia laxa*), cilindrosporiosis (*Blumeriella jaapii*), root-crown rot (*Phytophthora* spp.), and bacteria canker (*Pseudomonas syringae*). Twenty-one selected Iranian and seven introduced cultivars of sweet/sour/duke cherries were examined for resistance to bacterial canker (Farhadfar et al. 2016). Under field conditions 'Siyah-daneshkadeh' (sweet cherry cultivar) was rated as the most susceptible while 'Albaloo-meshkinshahr' (sour cherry cultivar) was collectively rated as the most resistant cultivar. Also, 'Siyah-mashhad' and 'Haj Yousefi' (sweet cherry cultivars) and the duke cherry cultivar, 'Albaloogilas-daneshkadeh', were ranked as intermediate in resistance. In conclusion, cherry cultivars vary in susceptibility to *P. syringae* pv. *syringae*, therefore, resistance or susceptibility to bacterial canker should be taken into consideration during orchard establishment/renewal.

Peach

Peach, *P. persica* (L.) Batsch (Fig. 4) grown throughout the warmer temperate regions of both the Northern and Southern hemispheres is thought to have originated in China, but was later introduced into Persia (Salunkhe and Desai 1984). Peach, which at one time was called "Persian apple", quickly spread from here to Europe (Lurie and Crisosto 2005). Their seed is enclosed in a hard, stone-like endocarp. Peach and nectarine are called 'Huloo' and 'Shalil', respectively in Iran. According to the latest available statistics of FAOSTAT (2016), Iran with 514,986 t production from 21,463 ha of harvested area is the 7th largest peach and nectarine producer in the world after China, Italy, Spain, USA, Greece and Turkey. Peach and nectarine are produced in different parts of Iran but Alborz and Mazandaran provinces are the main producers of these valuable fruits (Ministry of agriculture 2014). Peaches are cultivated commercially in Iran with the fruit being consumed fresh, canned, dried and processed into jelly, jam and juices. Double-flowering forms of peaches are cultivated as ornamentals.

Wild and domesticated genetic resources

Peaches and nectarines are mainly self-fertile and naturally self-pollinating fruit species with very low genetic variability. This species has been cultivated since ancient times in Iran but has changed greatly recently with many forms, including *P. persica* f.

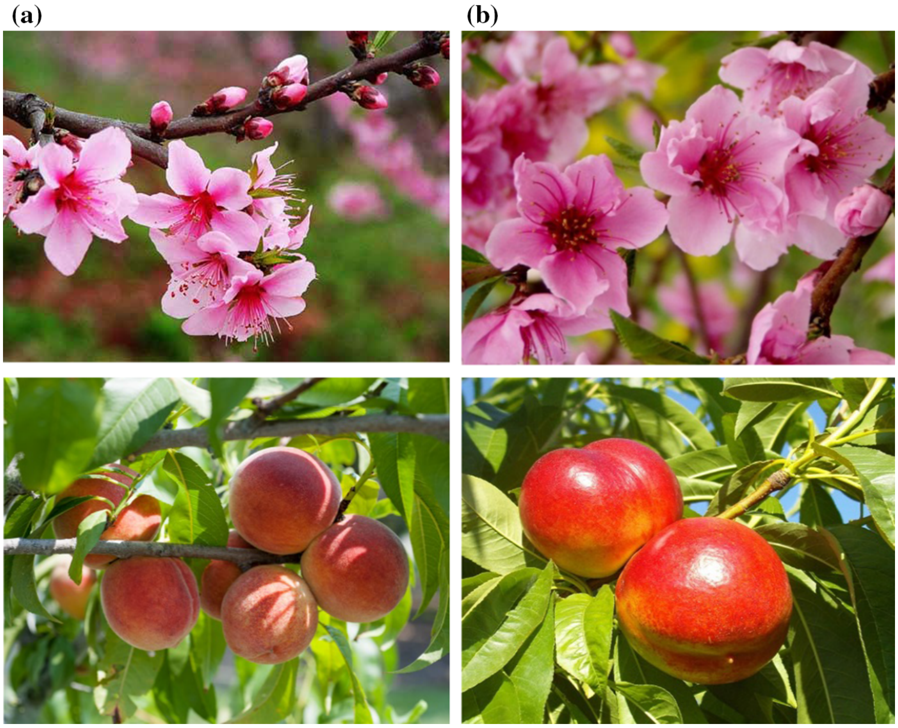

Fig. 4 Flowers and fruits of **a** peach (*P. persica* var. *vulgaris* Maxim.), and **b** nectarine (*P. persica* var. *nectarina* Maxim.)

atropurpurea Schneid. (with pink flowers), *P. persica* f. *alba* Schneid. (with white flowers), *P. persica* f. *duplex* Rehd. (with very dense double and pink flowers), *P. persica* f. *camelliaefolia* Dippel. (with very dense double and dark red flowers), *P. persica* f. *albo-plena* Schneid. (with double row and white flowers), *P. persica* f. *rubro-plena* Schneid. (with double row and red flowers), *P. persica* f. *magnifica* Schneid. (with double row and light red flowers), *P. persica* f. *dianthiflora* (Vanh.) Dipp. (with almost double row and pink flowers), *P. persica* f. *versicolor* (Vanh.) Voss (with almost double row, red or white and streaky flowers), *P. persica* f. *pyramidalis* Dippel. (with a thin pyramided vegetative form), *P. persica* f. *pendula* Dipp. (with overhanging branches), and *P. davidiana* (Carr.) Franch. (trees up to 10 m, with glaborous twigs and round yellowish fruits) (Mozaffarian 2005). Three varieties can be recognized taxonomically based on fruit morphology. The common peach (*P. persica* var. *vulgaris* Maxim.) has rounded and hairy fruits 5–7 cm in diameter. The nectarines (*P. persica* var. *nectarina* Maxim.) have rounded fruits that lack pubescence on the skin, which is controlled by a single locus (Lill et al. 1989). Also, nectarine cells have smaller intercellular spaces than peaches and are, therefore, denser. The flat peach [*P. persica* var. *platycarpa* Bailey (syn: *P. persica* var. *compressa* Bean.)] has flat fruits and a small pit (Mozaffarian 2005).

On the basis of separation of the stone from the flesh, peaches and nectarines can be divided into two groups: freestone peach (*P. persica* f. *aganopersica* (Reichb.) Voss): pit relatively free from the flesh and clingstone peach (*P. persica* f. *sclеropersica* (Reichb.) Voss): pit adheres to flesh (Mozaffarian 2005).

Today, most cultivated peachs and nectarines in Iran are improved or imported cultivars. Local cultivars also exist. Local famous cultivars include ‘Sorkh-Sefide Mashhad’, ‘Ghermeze Mashhad’, ‘Huloo Sefid-Zard’, ‘Anjiri-e Maleki’ (a flat cultivar) ‘Anjiri-e Tabestaneh’ (a flat cultivar), ‘Haj kazemi’, ‘Makhmali’ and ‘Shalile Shams’ (nectarine) Also, there is a specific type of peach in Iran which is called ‘shaftaloo’ with glaborous fruits that are small in size (fruits are smaller than those of nectarines) and green to cream in color.

Evaluation and use of genetic resources

There are some reports on the evaluation of genetic resources of local peach germplasm in Iran. Studies on peach and nectarine genotypes of East Azerbayjan (at Sahand research station), Ardabil (at Meshkin shahr research station) and Alborz (at Karaj research station) provinces resulted in the collection and identification of some superior genotypes (Fathi et al. 2008b; Imani 2009). Genetic diversity analysis of 123 peach genotypes from Khorasan province based on morphological markers (Raji et al. 2011) based on cluster analysis categorized the genotypes into 4 main groups based on fruit properties including size, flesh and peel color, rate of pubescence and fruit acidity. Fruit acidity, in particular, had a significant impact on genetic diversity.

Chilling injury of vegetative and generative buds, bark and wood during fall and winter seasons are among the main limiting factors for productivity of peaches and nectarines. Selecting and expanding cultivars for more yield and quality without considering frost resistance is practically not possible. Investigations into frost susceptibility of some peach and nectarine cultivars showed that 'Mashhad Sorkhsefid' and 'Mashhad Ghermez' cultivars (both native cultivars to Iran), had the most resistant reproductive buds (Aryanpooya et al. 2009; Shojaee et al. 2012). Studies on stigma receptivity in local peach cultivars ('Makhmali', 'Anjiri-e-tabestane', 'Anjiri-e maleki', 'Haj-kazemi' and 'Zoodras') using fluorescence microscopy for examination of in vitro germination and pollen-tube growth in the pistil, showed that all cultivars are self-compatible and male-fertile (Fakhimrezaei and Hajilou 2013).

Plums

Plum, *P.* × *domestica* L. (Fig. 5) is one of the most commercially important fruit species in Iran. Plums are temperate zone fruits, but are widely grown throughout the world, from the cold climate of Siberia to the sub-tropical conditions of the Mediterranean region (Son 2010). Plums represent a diverse group of fruits that include European, Asian, and American species, but the principal economically important plum species are *Prunus* × *domestica* L. and *P. salicina* Lindl. The cultivated European plum, *P.* × *domestica* L. is a hexaploid (2 n = 6, x = 42) that probably originated as a hybrid between *P. cerasifera* Ehrh. (diploid) and *P. spinosa* L. (tetraploid) (Hummer and Janick 2009). *P.* × *domestica* seems to have originated in southern Europe or western Asia around the Caucasus Mountains and the Caspian Sea, but is widespread in the Balkans and in mediterranean countries (Ramming and Cociu 1990). According to the latest available statistics of FAOSTAT (2016), Iran with 305, 262 t of production from 11,702 ha of harvestable area is the 6th largest plum and sloe producer in the world after China, Serbia, Romania, Chile, and Turkey in 2013. In Iran, the major plum and sloe production occurs in Khorasn, Alborz, Fars and Tehran provinces (Ministry of agriculture 2014). In Persian language, plum and sloe are called 'Aloo' and 'Aloocheh', respectively. Also, in the north of Iran several local names are used for sloe including 'Shal Holoo', 'Khooli', 'Hali', and 'Nisoogh'. Special types of plums are specific to Iran such as greengage (Goje Sabz), consumed when it is unripe as early season fruit. Different types of prunes (dried plum) are used as special dishes such as Persian prune stew (Khoresh-e Aloo). Also, in Iran, a tart fruit roll (Lavashak-e Aloo torsh) is made with sour plums and served as a favorite dessert especially for kids.

Wild and domesticated genetic resources

P. × *domestica* L., *P. spinosa* L., *P. divaricata* Ledeb., *P. cerasifera* Ehrh., *P.* × *bilireina* Andre., and *P.* × *dasycarpa* Ehrh. are the most important species and hybrids in Iran (Table 4). There are two alternative names for cherry plum including *P. divaricata* Ledeb. and *P. cerasifera* Ehrh. (Büttner 2001). The latter name is often used for cultivated forms, which are also referred to as myrobalan plums (Wöhrmann et al. 2011). There are about 75 cultivars of plum and prune native to Iran. Native *Prunus* species exist in diverse climates ranging from subarctic regions to dry deserts where they are subjected to high and low temperatures, high and low moisture conditions, and variable soil conditions. The most important local cultivars are 'Bokhara', 'Siah-e Karaj', 'Zard-e Arak', 'Shamsaei', 'Mirzaei', and 'Sadie Uremia' ('Goje Sadie Uremia') (Khoshkhui et al. 2004). Also, there are different types of prune (dried plum) in Iran, but 'Bokhara', 'Baraghan', 'Shoghani' and 'Torghabe' are the most common ones. The first attempt to revive genetic resources of plum and sloe was begun by researchers including Gohar Khai (1983), Attar (1989), Dabir-Eshrafi and Gohar Khai (1992). This resulted in the establishment

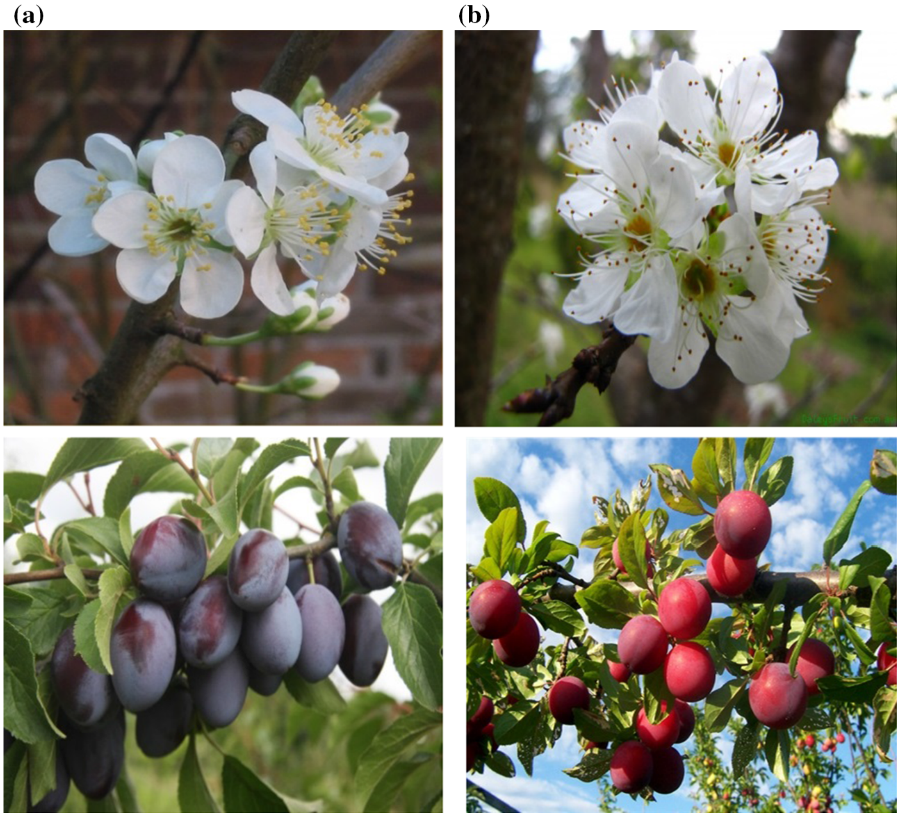

Fig. 5 Flowers and fruits of **a** European plum (*P.* × *domestica* L.), and **b** Japanese plum (*P. salicina* L.)

of the first collection consisting of 40 genotypes and local cultivars in research stations at Karaj and Khorasan and in 2009 this collection was upgraded to 60 cultivars (Abdollahi et al. 2010).

Evaluation and use of genetic resources

The wild cherry plum, *P. cerasifera* Ehrh. subsp. *divaricata* (Ledeb.) C. K. Schneid. (*P. divaricata* Ledeb.) is used as a rootstock for grafting *P.* × *domestica* cultivars and certainly has some potential for further domestication, to provide economic and livelihood benefits for subsistence farmers (Wöhrmann et al. 2011). Fruits are mainly collected from the forest. They are edible and used in several local foods (Khoshbakht and Hammer 2006). Individual wild cherry plum trees (*P. divaricata* Ledeb.) have been semi-cultivated for edible fruits, especially in home gardens along the Caspian coast (Khoshbakht et al. 2007). The fresh fruits are part of the diet of the local people, and are either eaten raw or used to prepare a local tart candy called ''Lavashak'' (Wöhrmann et al. 2011). Khoshbakht et al. (2007) reported that there are significant variation in pomological characteristics (such as fruit dimensions, fruit mass, flesh mass, nut mass, shell mass and kernel mass) between wild and semi-cultivated populations of this species (*P. divaricata* Ledeb.) in the southern part of the Caspian Sea. The cultivated form of cherry plum, *P. cerasifera* Ehrh., is an agriculturally important species, and is distinguished from other plums based on its drought tolerance, high resistance to root-knot nematodes and the suitability as a rootstock (Wöhrmann et al. 2011; Dirlewanger et al. 2004). The blackthorn, *P. spinosa*, is planted for soil stabilization and also as a hedge row for wind protection. The bitter fruits are used to make jellies, conserves and syrups and for various uses in folk medicine. The flowers are used as a blood cleaner and the leaves have been dried and used as a substitute for tea. Moreover, dyes have been obtained from the fruits, leaves and bark (Khoshbakht and Hammer 2006). While plums are mostly consumed as a fresh or

Table 4 Tree and fruit characteristics and distribution of plum species in Iran (Adapted from Khatamsaz 1992; Mozaffarian, 2005)

Species	Tree characteristics	Fruit properties	Distribution
P. × *domestica* L.	Mostly thornless trees or shrubs up to 12 m in height, with glaborous shoots or downy twigs	Drupe, oval or almost spherical in shape, up to 8 cm in length, green, yellow, red to purple and dark blue, with green or yellow pulp, sweet, easily or not easily detaching from the endocarp	In many parts of Iran including Giulan, Tehran, Fars, Khorasan, and Kermanshah provinces
P. cerasifera Ehrh. Var. *atropurpurea* Jaeg.	Trees up to 8 m, with thin branches, sometimes thorny, with glaborous twigs, white bloom and green leaves, but var. *atropurpurea* has purple leaves and flowers	Common names: cherry plum or myrobalan plum, almost spherical, red in color, 2–3 cm in diameter, with less waxy layer	In the north of Iran in Tehran province and the National Botanical Garden of Iran
P. divaricata Ledeb. Subsp. *divaricata* Subsp. *caspica* (Kov. et V. Ekim.) Browicz*	Deciduous thornless trees or shrubs up to 10 m in height, one year old shoots thin, erect, glaborous, glossy, green or red-brown in color	Common names: wild cherry plum or wild myrobalan plum, drupe spherical or elliptical–oblong, 15–30 mm in diameter, yellow, red or purple in color, astringent or bitter	In many parts of Iran including Golestan, Mazandaran, Giulan, Azerbayjan, Kermanshah, Hamadan, Lurestan, Fars, Khorasan, Semnan and Tehran provinces, subsp. *Caspica* is endemic to Iran
P. spinosa L.	Spiny, deciduous shrub, dense canopy with intricate branches and numerous suckers, hairy twigs which later become glaborous	The fruit, called "sloe", is a drupe, globose, 10–15 mm in diameter, ripening bluish-black with waxy layer, pulp greenish, sour and astringent or bitter, not easily detachable from the endocarp	North and northwest of Iran in Mazandaran (in Chaloos valley), Giulan, Azerbayjan (Ghareh Dagh and Arasbaran forest) provinces
P × *bilireina* Andre.	Small deciduous trees, 4.5–6 m tall, new leaves are pink and turn bronze-green in summer, spectacularly fragrant, semi-double, purple flowers. It is a cross between *P. cerasifera* var. *atropurpurea* × *P. mume*	Common name: the purple-leafed plum or double-flowering plum. Generally, most trees produce no fruit. When they do, the fruit is purple and edible	In the north of Iran in Tehran province and the National Botanical Garden of Iran
P × *dasycarpa* Ehrh.	Deciduous small trees up to 6 m high, with purplish, glaborous twigs. It is a cross between *P. armeniaca* × *P. cerasifera*	Common names: Purple apricot and black apricot, most trees produce no fruit. When they do, fruit is round, 3 cm in diameter, dark purple in color, with waxy layer and minutely downy	In the north of Iran including Tehran province and the National Botanical Garden of Iran

processed fruit, the prune-type plums produce a well-known product called prunes or dried plums. Prunes have long been a healthy product promoting digestive regularity among seniors, although the industry has developed moist types as a snack food (Hummer and Janick 2009). Among local genotypes, 'Tanasgol', a natural hybrid between apricot and plum (apricot prune) which is late blooming can be useful in breeding programs as a parent for producing late bloom genotypes (Aran et al. 2011). Moreover, using this 'Tanasgol' as an inter stock for 'Shahroodi' apricot, 'Baraghan' plum and 'Ghermeze Majlesi' plum cultivars can result in lower vegetative growth (Mir-Abdolbaghi 2010). In recent years, the genetic diversity of plum and sloe germplasm has been evaluated in Iran based on molecular markers including RAPDs (Aran et al. 2011; Darabifard et al. 2012), SSRs (Etehadpoor et al. 2012a, b; Wöhrmann et al. 2011) and expressed sequence tag-SSR (EST-SSR) (Wöhrmann et al. 2011), morphological characteristics (Khoshbakht et al. 2007; Sedaghathoor et al. 2009; Jalili et al. 2011; Ganji Moghadam et al. 2011; Darabifard et al. 2012).

Wöhrmann et al. (2011) examined genetic variation in wild populations of cherry plum (*P. divaricata* Ledeb.) sampled along the Iranian coast of the aspian sea (in northern Iran) using genomic SSR and EST-SSR markers developed in peach (*P. persica* (L.) Batsch) and Japanese plum (*P. salicina* Lindl.). Their results indicated high levels of genetic diversity and a lack of genetic differentiation of *P. divaricata* in northern Iran, suggesting that the natural populations of cherry plum in the Caspian forests are close to Hardy–Weinberg equilibrium and have not yet experienced measurable genetic drift. They also reported that the focus for in situ conservation should be on populations with the highest level of genetic diversity, such as the populations from Kashafi, Hashtpar, Asalem and Babol areas. The highly diverse *P. divaricata* populations could well turn out to be a valuable gene donor to increase variation in cultivated *Prunus* species by cross-breeding.

A study of genetic variation in 72 plum genotypes using RAPD markers showed relatively high genetic diversity among the genotypes (Aran et al. 2011). Cluster analysis based on the Jaccard's similarity coefficients and the unweighted pair-group method with arithmetic mean (UPGMA) at a similarity level of 0.58, divided the genotypes into 13 sub-clusters with 'Tanasgol' (natural hybrid between apricot and plum) being separated individually from other genotypes at a distance of 0.29. Aran et al. (2011) identified informative markers with the highest regression coefficient (r^2) as tree height, growth habit, leaf color and leaf width.

To study the genotypic diversity of prune and plum, 18 quantitative and qualitative characteristics of 38 genotypes were evaluated based on the International Board for Plant Genetic Resources (IBPGR) descriptors (Jalili et al. 2011). Variance analysis showed that most of the characteristics evaluated, were significantly different, in the genotypes indicating high variation. Cluster analysis (Ward method) divided genotypes into four main groups. These groups mainly differed in fruit and stone shape, self-compatibility and stone adherence to the flesh and had an effective role in cluster organizing (Jalili et al. 2011).

An important factor for successful plum cultivation is the knowledge of the cultivar's degree of self-compatibility. Diploid plum species such as *P. salicina* Lindl. and *P. cerasifera* Ehrh. are mostly self-incompatible, while fertility of the hexaploid European plum (*P.* × *domestica* L.) cultivars vary between self-compatibility, partial self-compatibility and self-incompatibility (Szabó 2003). There are also some male sterile plum cultivars (e.g. 'Crvena Ranka', 'Tuleu Gras', and 'Tuleu Timpuriu'). From production practice and breeding point of view, self-compatible cultivars are of the highest value, because when growing partially self-compatible, self-incompatible and self-sterile cultivars, it is necessary to provide adequate pollinizers (Nikolić and Milatović 2010). In this regard, the *S*-RNase genotypes of 34 plum genotypes from different areas in Iran, five commercial cultivars and a Mirobolan cultivar (making a total of 40 genotypes) were determined by PCR amplification of the *S*-RNase gene using degenerate primers (Etehadpoor et al. 2012b). Results suggested that PCR can be a rapid and effective method for identifying *S* genotypes in local plums. According to the results S_c, 621 bp and Si alleles had the highest frequencies (30, 17.5 and 12.5 percent respectively) while S_c had highest frequency in Iranian plums (17.1%) in Velian of Karaj population.

Apricot

According to the famous Russian Botanist Vavilov, there are three important regions where apricots, *Prunus armeniaca* L. (Fig. 6) originated, including the Chinese center (China and Tibet), the Central Asian center (from Tien-Shan to Kashmir) and the Near-Eastern (Irano–Caucasian) center (Iran, Caucasus, Turkey) (Yilmaz and Gurcan 2012). The Near-Eastern center could be a secondary gene center because of cultivated varieties and the absence of wild apricot forms according to Bailey and Hough (1975). The cultivars of eco-geographical groups in the Central Asian and Irano–Caucasian centers including Turkey and Iran show the richest phenotypic variability, while the European group including cultivars grown in North America, Australia and South Africa exhibit the least diversity (Halasz et al. 2010). Iran is very important for apricot production and has a long history of apricot cultivation as well as rich apricot germplasm (Raji et al. 2014). In 2013, Iran with 457,308 tonnes of production from 58,726 ha of cropping area is the 2nd

Fig. 6 Flowers and fruits of apricot (*P. armeniaca* L.)

largest apricot producer in the world after Turkey (FAOSTAT 2016). Most apricot production in Iran is located in the Semnan, Tehran, Yazd, Kerman and Fars provinces. However, the West Azerbayjan province with 10,461 ha has the largest harvestable area among the provinces in Iran (Ministry of agriculture 2014).

Apricot has an important place in human nutrition. The fruit of apricot is not only consumed fresh but can also be used to produce dried apricot, frozen apricot, jam, jelly, marmalade, pulp, juice, nectar, extrusion products, etc. Moreover, apricot kernels are used for the production of oils, Benzaldehyde, cosmetics, active carbon, and aroma perfume (Yildiz 1994). Apricot is rich in minerals such as potassium, and vitamins such as β-carotene which is the pioneer substance in minerals necessary for epithelia tissues covering our bodies and organs, eye-health, bone and teeth development and working of endocrine glands (Hacisefrogullari et al. 2006). In Iran, apricot is called 'Zardaloo', and dried apricot is known as 'Gheysii' among the ordinary people.

Wild and domesticated genetic resources

Iranian apricot germplasm is placed mainly into the Irano–Caucasian group. The secondary gene center of apricot, the Irano–Caucasian group, is generally self-incompatible, but on the contrary, they produce large fruits and bloom earlier than the apricots of Central Asia and require lower chilling hours (Yilmaz and Gurcan 2012).

P. armeniaca L. (apricot): Trees are up to 15 m in height, with spherical canopy, gray–brown bark, glaborous and glossy twigs, The fruit is a drupe, 2.5–5 cm in diameter, from yellow to orange, often tinged red on the side mostly exposed to the sun, glaborous or velvety with very short pubescence. This species is cultivated in many parts of Iran. The Iranian apricot germplasm is quite a genetically rich population. In the past, most apricot trees in Iran have been propagated by seed, so there were numerous cultivars and strains resulting from that (Arzani et al. 2005). The identification and classification of apricot cultivars belonging to this species is complicated due to numerous duplicates and/or synonyms (Nejatian 2003). Probably, several cultivars are indicated by the same name (homonyms), or the same cultivar is known by different names (synonyms) in either the same or different environments (Arzani et al. 2005). Most important local cultivars include 'Shahroodi', 'Jahangiri', 'Nasiri', 'Noori', 'Shekarpareh', 'Zia-maleki', 'Ordobad', 'Nakhjavan', 'Mirzaei', 'Shams', 'Tabarzeh', 'Ghorban-e-Maragheh', 'Gheysii'. 'Noori-Dirras' is a cultivar tolerant to late spring frost (Raji et al. 2014).

P. mandshurica Koehne (Manchurian apricot): Small trees up to 5 m in height, with spreading branches, round yellow fruit, 2.5 cm in diameter, small stone with a dull edge, planted in the National Botanical Garden of Iran (Mozaffarian 2005).

P. dasycarpa Ehrh. (Purple apricot or apricot plum): Small deciduous trees up to 6 m high, with purplish, glaborous twigs, with most trees producing no fruit. When they do bear fruit, the fruits are round, 3 cm in diameter, dark purple in color, with a waxy layer and minutely downy. This species arose from a cross between *P. armeniaca* × *P. cerasifera*. They are mostly planted in the north of Iran in Tehran province and at the National Botanical Garden of Iran (Mozaffarian 2005). 'Tanasgol' leaves are similar to apricot, but its fruit is similar to plum. The fruit taste is tart and is a late blooming cultivar. These characteristics make 'Tanasgol' a cultivar of interest as a parent in breeding programs to transfer the late flowering trait. The characteristics of *P.* × *dacycarpa* Ehrh., are very similar to 'Tanasgol', although more studies are required to understand the relationship between them (Raji et al. 2014).

Evaluation and use of genetic resources

Germplasm collection and characterization is an early essential stage to initiate a breeding program for diversity. In this regard, collection and conservation of 170 accessions of the genetic resources of apricot from Semnan (Shahrood), Khorasan, Tehran, west Azerbayjan, Kurdistan, Ghazvin and other regions is noteworthy (Mostafavi 1991; Mansourfar 1994; Bouzari et al. 2009b; Dejampour 2009; Rahnemoon 2010; Abdollahi et al. 2010).

Different types of marker systems including morphological, molecular, and biochemical have been used for genetic analysis of apricot germplasm. Among the DNA markers, RAPDs (Jannatizadeh et al. 2011 and Mohammadzadeh et al. 2013), flurescent-AFLP (Majidian et al. 2011) and SSRs (Najafi et al. 2012; Raji et al. 2014) are the most frequently used for assessment of genetic variability and relationships among Iranian apricot cultivars. These studies demonstrate that the Iranian apricot germplasm provide a high level of genetic diversity. It appears that the *Prunus* SSR loci are highly conserved and can be used in apricot-breeding programs to maximize genetic variability which will be useful in generating new cultivars (Raji et al. 2014). According to Majidian et al. (2011), the flurescent-AFLP markers classified apricot genotypes into six groups corresponding to their origin and geographical distribution. In comparison to traditional AFLP markers, the fluorescent-AFLP markers appear more efficient in the understanding of genetic diversity and population structure in apricots and may be useful in other *Prunus* fruit tree species as well.

Evaluation of Iranian apricot germplasm shows potential for selecting apricot accessions according to their ripening season, fruit size, and TSS/TA ratio (Jannatizadeh et al. 2011; Raji et al. 2014).

Similar to other *Prunus* species, apricots show gametophytic self-incompatibility controlled by a single locus with multiple genes, *S*-haplotypes (De Nettancourt 2001). The Irano–Caucasian group is usually self-incompatible whereas, the Europan apricots are mostly self-compatible (Yilmaz and Gurcan 2012). Iranian apricots have been shown to be mainly self-incompatible based on self-pollen tube growth observations under fluorescence microscopy, pollen germination in vitro, pistil and ovary length and diameter, fruit set after self-pollination under field conditions, PCR and sequencing approaches (Nejatian and Arzani 2004; Nejatian and Ebadi 2006; Hajilou et al. 2006a; Nekonam et al. 2011; Gharebeikloo et al. 2013; Molaie et al. 2014). Also, the existence of cross-incompatibility between some Iranian apricot cultivars has been documented by Hajilou et al. (2006a) and Molaie et al. (2014). According to Hajilou et al. (2006a), the cultivars, 'Ghorban-e-Marageh' and 'Ghermez-e-Shahroodi' were self-compatible and, interestingly, shared a PCR band with all Spanish self-compatible apricot cultivars examined to date. Also, research has shown that the *S*-genotypes in the progenies from 'Goldrich' × 'Pepito' cross were detected as *ScS1* and *ScS2* in 6 and 3 seedlings, respectively. Furthermore, self-compatible progenies were determined when self-compatible cultivars were inter-crossed or with self-incompatible cultivars (Hajilou et al. 2006b).

Despite an increase in production in the 50 years, world production of apricot is actually low due to limited capabilities of adaptation to different environments, limited number of varieties, self-incompatibility, frost damage, and susceptibility to Sharka and Monilinia (*Sclerotinia laxa* Aderh et. Ruhl.) (Yilmaz and Gurcan 2012). Apricot cultivation in different parts of Iran is still very traditional and in most years, late spring frost (February and March) usually damages flowers and reduce yield. Early flowering and the use of late frost susceptible cultivars in orchards are the most important issues and the main priorities of apricot breeding programs in Iran to develop cultivars resistant to late spring frost. However, no frost resistant cultivar has been released to date due to lack of genotypes exhibiting resistance to late spring frost in the wild apricots and germplasm collections. Although, breeding programs for selecting or producing resistant genotypes are being developed especially, at the Sahand horticultural research station and some other research stations. Razavi et al. (2011) reported that peach and apricot have close chilling requirements, although the heat requirement of apricot cultivars was lower than that of peach cultivars. The lower heat requirement observed in apricot cultivars indicates the risk of growing this cultivar in cold areas, because flowering happens too early than in peach and low temperatures can induce a loss of yield by early spring frosts. Evaluation of super-cooling temperatures in flowers of apricot cultivars 'Noori-Dirras' and

'Nasiri' showed that the lowest super-cooling temperature was −6.1 °C recorded at the full bloom stage in Nori-Dirras' suggesting that this cultivar is tolerant to late spring frost (Jannatizadeh et al. 2014). The results of 21 years of study in order to select spring frost resistant apricot germplasm (evaluating more than 120 genotypes) by Javaherdeh (2009) at the Shahrood research station in Semnan province clustered 110 genotypes into a very susceptible group while only two cultivars 'Jahangiri' and 'Khieba-e-bastam' were placed in a very resistant group. In addition, 'Noori-Dirras' and 'Noori-Zoodras', 'Ghorban-e-Maraghe' and 'Stiut-e-Maraghe' were found in the resistant group.

In 2011, four new cultivars including 'Ordobad-90', 'Nasiri-90', 'Maraghe-90' and 'Aibatan' from the Irano–Caucasian group were released from selection programs of local cultivars with superior fruit quality that are suitable for both processing as dried fruit as well as for table fruit consumption at the Sahand research station (Seed and plant improvement institute 2016). In 2014, a very promising dwarf rootstock SJ/M has been released from the Sahand research station which decreased the canopy volume of apricots by up to 50% (East Azerbayjan Research and Education Center for Agriculture and Natural Resources 2016). This rootstock is a cross between native and foreign apricot germplasm.

Conservation of genetic resources of stone fruits in Iran

The survival of most natural habitats for plant genetic resources is being threatened by urbanization, industrialization, road construction, fires, drought, pollution, indiscriminate use of herbicides and pesticides, overgrazing, etc. It behooves germplasm exploration scientists to collect these wild genetic resources for conservation in gene banks. In addition, evaluation, characterization and enlargement of the germplasm diversity represented in ex situ and in situ collections are important to plant breeders for crop improvement and to multiple stakeholders for efficient use and effective management of plant genetic resources. The genetic resources of stone fruits in Iran are mainly conserved in ex situ collections in research stations across the country especially at Sahand, Kamalshahr, Shahrood and Mashhad horticultural research stations. The protected area 'Mian Jangal' in Fars province is the only in situ collection in Iran for wild almond species such as *P. scoparia*, *P. erioclada* and *P. lycioides*. The morphological, molecular, biochemical characterization of stone fruit accessions enhance the value and potential utilization of the germplasm, thus making it available at the international level. Introduction of new cultivars either through breeding or selection programs, improved propagation techniques and use of biotechnology are contributing to the replacement of local cultivars and land races by new commercial cultivars.

Conclusion

There is a large diversity of genetic resources of stone fruits including commercial cultivars, landraces and wild species in Iran. This diversity encompasses almost all key morphological and pomological traits, as well as, resistance/tolerance to biotic and abiotic stresses. Some accessions have potential to be utilized directly as new scion or rootstock cultivars, while many could be utilized indirectly through breeding programs as parents to develop new superior cultivars with novel traits. However, the survival of most natural habitats for these genetic resources is being threatened by urbanization, industrialization, road construction, arson and fires, drought, indiscriminate use of agricultural practices, overgrazing, etc. The research centers including those belonging to Iranian Institute for Horticultural Research as well as important public universities have done a lot of research on evaluation, identification, conservation and characterization of the genetic resources of stone fruits. Nonetheless, the approaches need to be modernized to cope with current and future challenges. Besides, comprehensive and efficient in situ conservation programs in natural habitats for the genetic resources, new genetic resources must be explored, exploited and included in existing collections through tissue culture and traditional propagation techniques. The emphasis of collection efforts should be on wild types, especially, in sites that are in danger of deterioration. Although some breeding activities are taking place, these efforts are scattered and need to be harmonized among different sectors including the academia, and the ministry of agriculture and private sectors.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

References

Abdollahi H, Hasani D, Imani A, Bouzari N, et al (2010) Genetic resources of Iranian fruit trees. In: Proceedings of 11th congress of Iranian genetics society, Shahid Beheshti Univ, Tehran, Iran, pp 85–89 (in Farsi)

Abedian M, Talebi M, Golmohammdi HR, Seyed-Tabatabaei BE (2012) Genetic diversity and population structure of mahaleb cherry (*Prunus mahaleb* L.) and sweet cherry (*Prunus avium* L.) using SRAP markers. Biochem Syst Ecol 400:112–117

Abolghasemi S (2011) Biosphere reserve management mechanisms. J Natl Sci Found Sri Lanka 31(1–2):275–290

Ahmadi Moghadam H, Ganji Moghadam E, Akhavan S (2012) Evaluation of quantitative and qualitative chracteristics of some selected sweet cherry genotypes. Seed Plant Improv J 28(2):187–200 (in Farsi)

Amiri ME (2007) Special micrografting technique for cherry (*Prunus avium* L.). Acta Hortic 764:151–154

Ansari A, Gharaghani A (2016) Evaluation and comparison of tree and nut characteristics in two wild almond species (*Amygdalus elaeagnifolia* Spach and *Amygdalus scoparia* Spach). In: International symposium on role of plant genetic resources on reclaiming lands and environment deteriorated by human and natural action, Shiraz university, Shiraz, Iran. Abstract book, p 48

Aran M, Fatahi MM, Zamani Z (2011) Genetic diversity among plum genotypes using RAPD molecular markers. Iran J Hortic Sci Technol 12(1):39–52 (in Farsi)

Ardjmand A, Piri S, Imani A (2014) Evaluation of morphological and pomological diversity of 62 almond cultivars and superior genotypes in Iran. J Nuts 5(1):39–50 (in Farsi)

Aryanpooya Z, Davarynejad GH, Attar Sh (2009) Investigation of frost susceptibility of some peach and nectarine cultivars in the winter of 2008, Mashhad, Iran. J Hortic Sci 23(1):78–87 (in Farsi)

Arzani K, Khalighi A, Mostafavi M, Maniei A, Vojdani P (1992) Selection of the best pollinizer for sweet cherry (*Prunus avium* var: "Siah Mashhad"). Iran J Agric Sci 23(1):57–65 (in Farsi)

Arzani K, Nejatian MA, Karimzadeh G (2005) Apricot (*Prunus armeniaca*) pollen morphological characterization through scanning electron microscopy, using multivariate analysis. N Z J Crop Hortic Sci 33(4):381–388

Asghari H (2003) Study of incompatibility and pollen tube growth in some sweet cherry cultivars with Haj Yousefi cultivar. MSc. Thesis, College of Agriculture, Tarbiat Modarres, University, Tehran, Iran (in Farsi)

Attar A (1989) Preliminary study of plum varieties as the inter stock to produce dwarf hanging crown apricots trees. Final report of a research project. Seed and Plant Improvement Research Institute, Karaj, Iran (in Farsi)

Attar F, Maroofi H, Vafadar M (2009) *Amygdalus kurdistanica* and *A. orazii* spp. nov. (Rosaceae) from Iran. Nord J Bot 27(4):324–327

Bailey LH, Hough LF (1975) Apricots. In: Janick J, Moore JN (eds) Advances in fruit breeding. Purdue University Press, West Lafayette, pp 367–383

Baninasab B, Rahemi M (2007) Evaluation of three wild species of almond on the basis of their morphological characters. J Cent Eur Agric 7(4):619–626

Batlle I, Ballester J, Boskovic R, Romero MA, Tobutt KR, Vargas FJ (1997) Use of stylar ribonucleases in almond breeding to design crosses and select self-compatible seedlings. FAO CIHEAM Netw Nuts Nucis-Newsl 6:12–14

Bouzari N, Ebrahimzadeh H, Arzani K (2006) A study of genetic diversity with the use of protein markers in sweet cherry (*Prunus avium* L.). Iran J Agric Sci 37(3):389–396 (in Farsi)

Bouzari N, Karami F, Ghasemi A, Mozafari MR, Hasani GH, Ahmadi J, Zeraatgar H, Jolodar J, Dorostkar M, Ganji Moghadam A, Zarinbal M (2009a) Sour cherry indigenous germplasm collection and evaluation in order to achieve a suitable rootstock and varieties. Final report of a research project. Seed and Plant Improvement Research Institute Publication, Karaj, Iran (in Farsi)

Bouzari N, Ahmadi J, Zeraatgar H (2009b) Identification, collection and evaluation of local apricot germplasm. Final report of a research project. Seed and Plant Improvement Research Institute, Karaj, Iran (in Farsi)

Browicz K, Zohary D (1996) The genus *Amygdalus* L. (Rosaceae): species relationships, distribution and evolution under domestication. Genet Resour Crop Evol 43:229–247

Buman G (1977) Clonal selection in *Prunus mahaleb* rootstocks. Acta Hortic 75:139–148

Büttner R (2001) Prunus sect Prunus. In: Hanelt P, Institute of Plant Genetics, Crop Plant Research (eds) Mansfeld's encyclopedia of agricultural and horticultural crops, vol 1. Springer, Berlin, pp 517–523

Bybordi A (2013) Assessment of tolerance of late-flowering almond cultivars to salinity. J Crop Prod Process 3(9):217–226 (in Farsi)

Chaichi S (1999) Genetic modification of almond. The first national symposium on almond. Agriculture Training Publication 1, p 30 (in Farsi)

Chaichi S, Eskandari S (1999) Evaluation of native cultivars of almond in East Azarbaijan province from view point of late flowering and quality of kernel. The first national symposium on almond. Agriculture Training Publication 1, p 42 (in Farsi)

Chin SW, Shaw J, Haberle R, Wen J, Potter D (2014) Diversification of almonds, peaches, plums and cherries—molecular systematics and biogeographic history of *Prunus* (Rosaceae). Mol Phylogenet Evol 76:34–48

Dabir-Eshrafi P, Gohar Khai S (1992) Preliminary Study of plum and sloe cultivars, Final report of a research project. Seed and Plant Improvement Research Institute, Karaj, Iran (in Farsi)

Daneshvar Hosseini AR, Moghadam EG, Khorasani SK, Bihamta MR (2011) Effects of growth regulators on micro propagation of some Mahaleb dwarf genotypes (*Prunus mahaleb* L.). Arch Appl Sci Res 3(1):118–125

Darabifard H, Bouzari N, Abdossi V (2012) Genetic diversity in some Plum (*Prunus* spp.) cultivars using morphological characteristics and molecular markers. Seed Plant Improv J 28(4):643–661 (in Farsi)

De Nettancourt D (2001) Incompatibility and incongruity in wild and cultivated plants, 2nd edn. Springer, New York

Dehshiri MM, Mozaffarian V, Ahmadi M (2012) *Cerasus paradoxa* (Rosaceae), a new species from Iran. Iran J Bot 18(2):220–223

Dejampour J (2009) Introduce new apricot genotypes from breeding program in Sahand Horticulture Research Station. In: Proceeding of 6th congress of Iranian horticultural science. Guilin Univ, Iran (in Farsi)

Demirsoy H, Demirsoy L (2004) Characteristics of some local sweet cherry cultivars from Homeland. J Agron 3:88–89

Dicenta F, Garcia JE (1993) Inheritance of self-compatibility in almond. Heredity 70:313–317

Dirlewanger E, Posson P, Howad W, Capdeville G, Bosselut N, Claverie M, Voisin R, Poizat C, Lafargue B, Baron O, Laigret F, Kleinhentz M, Arús P, Esmenjaud D (2004) Microsatellite genetic linkage maps of myrobalan plum and an almond-peach hybrid—location of root-knot nematode resistance genes. Theor Appl Genet 109:827–838

East Azerbaijan Research and Education Center for Agriculture and Natural Resources (2016) http://azaran.areo.ir/DesktopModules/News/NewsView.aspx?TabID=3745&Site=azaran.areo&Lang=fa-IR&ItemID=43290&mid=21516&wVersion=Staging. Accessed 20 Nov 2016 (in Farsi)

Eisenman SW (2015) Some nomenclatural adjustments and typifications for almond species in the genus *Prunus* sensu lato (Rosaceae). Phytotaxa 222(3):185–198

Ershadi A, Moghadam EH (2009) Identification of s-alleles in 25 sweet cherry (*Prunus avium* L.) Cultivars by allele-specific PCR amplification. Acta Hortic 814:619–622

Eskandari S, Majidazar M (2009) Introduction of new hybrid varieties of almond (*Prunus amygdalus* Batsch) for almond producing regions of Iran. World Appl Sci J 6(3):323–330

Etehadpoor M, Fattahi Moghadam MR, Zamani Z (2012a) Genetic diversity of wild and commercial genotypes of plum using SSR molecular marker. Iran J Hortic Sci 43(2):199–210 (in Farsi)

Etehadpoor M, Fattahi Moghadam MR, Zamani Z (2012b) Identification of self-incompatibility alleles in Iranian native and some commercial plums using allele specific amplification by PCR. Mod Genet J 7(1):47–55 (in Farsi)

Evreinoff VA (1958) Contribution a letude de l'amandier. Fruits et primeurs Afrique 28:99–104

Fakhimrezaei S, Hajilou J (2013) Evaluation of stigma receptivity period in several peach cultivars through controlled pollination under field and laboratory condition. J Hortic Sci 27(3):286–294 (in Farsi)

FAOSTAT (2016) Food and Agriculture Organization of the United Nations. http://faostat3.fao.org/download/Q/QC/E. Accessed 22 May 2016

Farhadfar S, Keshavarzi M, Bouzari N, Moghadam L, Soleimani A (2016) Susceptibility of cherries to bacterial canker (*Pseudomonas syringae* pv. syringae) in field and laboratory. Int J Agric For 6(1):20–27

Farsad A, Esna-Ashari M (2016) Genetic diversity of some Iranian sweet cherry (*Prunus avium*) cultivars using microsatellite markers and morphological traits. Cytol Genet 50(1):8–19

Fathi A, Ghareyazi B, Haghnazari A, Ghaffari MR, Pirseyedi SM, Kadkhodaei S, Nghavi MR, Mardi M (2008a) Assessment of the genetic diversity of almond (*Prunus dulcis*) using microsatellite markers and morphological traits. Iran J Biotechnol 6(2):98–106

Fathi H, Dojampour J, Jahani Y, Ramazani H, Emami GH (2008b) Identification and collection of peach and nectarine genotypes with desirable traits in Ardabil and East Azerbaijan province. Final report of a research project. Seed and Plant Improvement Research Institute Publication, Karaj, Iran (in Farsi)

Fernández i Martí A, i Forcada CF, Kamali K, Rubio-Cabetas MJ, Wirthensohn M (2015) Molecular analyses of evolution and population structure in a worldwide almond [*Prunus dulcis* (Mill.) D.A. Webb syn. *P. amygdalus* Batsch] pool assessed by microsatellite markers. Genet Resour Crop Evol 62(2):205–219

Firuz E (1974) Environment Iran. The National Society for the Conservation of Natural Resources and Human Environment, Tehran, Iran

Ganji Moghadam A (2011). Investigating the possibility of in vitro propagation of selected Cherry dwarf rootstocks. Final report of a research project. Seed and Plant Improvement Research Institute Publication, Karaj, Iran (in Farsi)

Ganji Moghadam E, Khalighi A (2006) Genetic variation of mahaleb (*Prunus mahaleb* L.) on some Iranian populations using morphological characters. J Appl Sci 6(3):651–653

Ganji Moghadam E, Khalighi A (2007) Relationship between vigor of Iranian *Prunus mahaleb* L. selected dwarf rootstocks and some morphological characters. Sci Hortic 111:209–212

Ganji Moghadam E, Hosseini P, Mokhtarian A (2009) Blooming phenology and self-incompatibility of some commercial cherry (*Prunus avium* L.) cultivars in Iran. Sci Hortic 123:29–33

Ganji Moghadam E, Hossein Ava S, Akhavan S, Hosseini S (2011) Phenological and pomological characteristics of some plum (*Prunus* spp.) cultivars grown in Mashhad, Iran. Crop Breed J 1(2):105–108

Ganji Moghadam E, Ahmadi Moghadam H, Piri S (2013) Genetic variation of selected Siah Mashhad sweet cherry genotypes grown under Mashhad environmental conditions in Iran. Crop Breed J 3(1):45–51

Ganji-Moghadam E, Mokhtarian A, Kiani MR (2006) Investigation on genetic variation of sour cherry (*Prunus cerasus* L.) populations for selection of dwarf genotypes using morphological characters. Seed Plant Improv J 22(4):417–428 (in Farsi)

Gentry HS (1956) Almond culture in southern Iran. Almond Facts 21:67

Ghanji Moghadam E (2004) Collection, characterization and conservation of stone fruit trees in Khorasan, Iran. Final report of a research project. Khorasan Agricultural and Natural Resources Research Center Publication, Khorasan, Iran (in Farsi)

Gharaghani A, Eshghi S (2015) *Prunus scoparia*, a potentially multi-purpose wild almond species in Iran. In: II

International symposium on wild relatives of subtropical and temperate fruit and nut crops. Acta Hortic 1074:67–72

Gharebeikloo S, Gharesheikhbayat R, Davoodi D (2013) Self-(in) compatibility status of some promising apricot (*Prunus armeniaca* L.) genotypes evaluated by fruit set tests and pollen tube growth observation. In: Proceedings of the 8th Iranian horticultural science congress, Hamadan, Iran (in Farsi)

Gharooni T, Zamani Z, Bouzari N (2012) Genetic variation of mahaleb (*Prunus mahaleb* L.) genotypes based on morphological traits and RAPD primers. Seed Plant Improv J 28(4):717–721 (in Farsi)

Gholami M, Rahemi M, Kholdebarin B (2010) Effect of drought stress induced by polyethylene Glycol on Seed Germination of four wild almond species. Aust J Basic Appl Sci 4(5):785–791

Gohar Khai SH (1983) Preliminary study of plum cultivars in terms of quantity, quality and performance and their relationship with other vegetative and reproductive factors. Final report of a research project. Seed and Plant Improvement Research Institute, Karaj, Iran (in Farsi)

Gohar Khai SH (1987) A primary study on sweet cherry varieties. Final report of a research project. Seed and Plant Improvement Research Institute Publication, Karaj, Iran (in Farsi)

Gradziel TM (2011) Origin and dissemination of almond. Hortic Rev 38:23–81

Gradziel TM, Martínez-Gómez P (2002) Shell seal breakdown in almond is associated with the site of secondary ovule abortion. J Am Soc Hortic Sci 127:69–74

Gradziel TM, Martínez-Gómez P, Dicenta F, Kester DE (2001) The utilization of *Prunus* species for almond variety improvement. J Am Pomol Soc 55:100–108

Hacisefrogullari H, Gezer I, Ozcan MM (2006) Post harvest chemical and physicalmechanical properties of some apricot varieties cultivated in Turkey. J Food Eng 79:364–373

Hafizi A, Shiran B, Maleki B, Imani A, Banović B (2013) Identification of new S-RNase self-incompatibility alleles and characterization of natural mutations in Iranian almond cultivars. Trees 27(3):497–510

Hajilou J, Grigorian V, Mohammadi SA, Nazemmieh A, Romero C, Vilanova S, Burgos L (2006a) Self- and cross-(in)compatibility between important apricot cultivars in northwest Iran. J Hortic Sci Biotechnol 81(3):513–517

Hajilou J, Mohammadi SA, Gerigurian V, Nazemiye A, Burgos L (2006b) Identification of S-alleles in some apricot cultivars and their segregations in some genotypes using specific primers. Iran J Hortic Sci Technol 6:103–114 (in Farsi)

Halasz J, Pedryc A, Ercisli S, Yilmaz KU, Hegedus A (2010) *S*-genotyping supports the genetic relationships between Turkish and Hungarian apricot germplasm. J Am Soc Hortic Sci 135(5):410–417

Hasani Moghadam E (2006) Identification of S-Alleles in sweet cherry cultivars by allel specific amplification PCR. MSc. Thesis, Faculty of Agriculture, University Bu-AliSina, Hamedan, Iran (in Farsi)

Homayouni A, Bouzari N, Abdousi V (2012) Genetic diversity of some Iranian sour cherry genotypes based on morphological and molecular markers. Seed Plant Improv J 28(2):239–254 (in Farsi)

Hummer KE, Janick J (2009) Rosaceae: taxonomy, economic importance, genomics. Genetics and genomics of Rosaceae. Springer, New York, pp 1–17

Iezzoni AF (2008) Cherries. In: Hancock JF (ed) Temperate fruit crop breeding. Springer, Berlin, pp 151–175

Imani A (2009) Investigation of quality and quantity characteristics of some of local and imported peaches and nectarines in Kraj condition. Final report of a research project. Seed and Plant Improvement Research Institute Publication, Karaj, Iran (in Farsi)

Imani A (2015) An analysis on the research achievement of past three decades on almond breeding with emphasis frost spring in Iran. In: Proceeding 9th Iranian congress of horticultural sciences, Chamran University, Ahvaz, Iran, pp 1–5 (in Farsi)

Imani A, Eksiri S, Piri S, Davoodi D (2013) Effects of pollen source on fruit set and pollen tube growth of sweet cherry (*Prunus avium* L.) cv. 'Tak Daneh Mashhad'. J Basic Appl Sci Res 3(2s):575–580

Izadpanah M (2001) Propagation of wild cherry (*prunus avium*) through in vitro culture. Pazhohesh va Sazandegi 3(14):68–74 (In Farsi)

Jalili E, Rabiei V, Azami MA, Daghestani M (2011) Genotypic diversity of prune and plum using morphological characteristics in Maragheh region. Seed Plant Improv J 27(3):357–374 (in Farsi)

Jannatizadeh A, Fattahi Moghadam MR, Zamani Z, Zeraatgar H (2011) Investigation of the genetic diversity of apricot varieties and cultivars using RAPD markers and morphological traits. Iran J Hortic Sci 42(3):255–265 (in Farsi)

Jannatizadeh A, Fattahi Moghadam MR, Zamani Z, Babalar M, Abbasi A, Abedini M (2014) Evaluation or supercooling temperatures in apricot flowers. Iran J Hortic Sci 45(1): 35–43 (in Farsi)

Javaherdeh M (2009) Apricot spring frost damages: a twenty-years study in order to select spring frost resistant apricot germplasms. In: Proceeding of 6th congress of Iranian horticultural science. Guilin Univ, Iran (in Farsi)

Kadkhodaei S, Shahnazari M, Nekouei MK, Ghasemi M, Etminani H, Imani A, Ariff AB (2011) A comparative study of morphological and molecular diversity analysis among cultivated almonds (*Prunus dulcis*). Aust J Crop Sci 5(1):82

Khadivi-Khub A, Anjam K (2014) Morphological characterization of *Prunus scoparia* using multivariate analysis. Plant Syst Evol 300(6):1361–1372

Khadivi-Khub A, Zamani Z, Bouzari N (2008) Evaluation of genetic diversity in some Iranian and foreign sweet cherry cultivars by using RAPD molecular markers and morphological traits. Hortic Environ Biotechnol 49(3):188–196

Khadivi-Khub A, Zamani Z, Fattahi R, Wünsch A (2014) Genetic variation in wild *Prunus* L. subgen. Cerasus germplasm from Iran characterized by nuclear and chloroplast SSR markers. Trees 28:471–485

Khatamsaz H (1992) Iran's Flora, Rosaceae. Research Institute of Forests and Range lands, Tehran (in Farsi)

Khorasan Razavi Agricultural and Natural Resources Research Center (2016) http://kanrrc.areo.ir/DesktopModules/News/NewsView.aspx?TabID=18325&Site=kanrrc.areo&ItemID=59892&mid=31848&wVersion=Staging&lang=fa-IR. Accessed 14 June 2016 (in Farsi)

Khoshbakht K, Hammer K (2006) Savadkouh-an evolutionary center for fruit trees and shrubs. Genet Resour Crop Evol 53:641–651

Khoshbakht K, Reza MA, Hammer K (2007) Phenotypic diversity of fruits and kernels of *Prunus divaricate* Ledeb. in Northern Iran-implications for domestication and utilisation. Tropentag, October 9–11, Witzenhausen

Khoshkhui M, Shaybani B, Rouhani I, Tafazoli E (2004) Principles of horticultural science. Shiraz Univ press, Shiraz, pp 417–418 (in Farsi)

Ladizinsky G (1999) On the origin of almond. Genet Resour Crop Evol 46:143–147

Lill RE, O'Donaghue EM, King GA (1989) Postharvest physiology of peaches and nectarines. Hortic Rev 11:413–452

Lurie S, Crisosto CH (2005) Chilling injury in peach and nectarine. Postharvest Biol Technol 37(3):195–208

Madam B, Rahemi M, Mousavi A, Martínez-Gómez P (2011) Evaluation of the behavior of native Iranian almond species as rootstocks. Int J Nuts Related Sci 2(3):29–34

Madani B, Rahemi M, Assad MT, Tafazoli E, Mardani AA (2006) A study on morphological, cytogenetic and grafting take of five almond rootstocks. M.Sc. Thesis, University of Shiraz, Shiraz, pp 92

Mahmoudi M, Arzani K, Bouzari N (2007) Pollination, pollen tube growth and determination of suitable pollinizer for sweet cherry (*Prunus avium* L.) cultivar Ghermez Rezaeieh. Seed Plant Improv J 23(4):571–585 (in Farsi)

Majidian P, Zeinalabedini M, Dejampour J, Najafi H, Mardi M, Dabbab M, Farsi M (2011) Study of genetic diversity and eco-geographic groups in some apricot cultivars and genotypes using fluorescent-AFLP markers. J Agric Biotechnol 3(1):67–76 (in Farsi)

Mansourfar H (1994) Collecting and studying of botanical agronomic characteristics of native and foreign varieties of apricot. Final report of a research project. Seed and Plant Improvement Research Institute, Karaj, Iran (in Farsi)

Mehdigholi K, Sheidai M, Niknam V, Attar F, Noormohammadi Z (2013) Population structure and genetic diversity of *Prunus scoparia* in Iran. Ann Bot Fenn 50(5):327–336

Ministry of agriculture (2014) Annual book of statistics forhorticultural crops. http://www.maj.ir/Portal/File/ShowFile.aspx?ID=d017b964-cbc7-4c70-84e6-1c928aca0b2f (in Farsi)

Mir-Abdolbaghi M (2010) Collection and evaluation of natural hybrids of apricot prune to use as rootstock/inter stock for apricot, plum and prune cultivars. Final report of a research project. Seed and Plant Improvement Research Institute, Karaj, Iran (in Farsi)

Mohammadzadeh S, Bouzari N, Abdoosi V (2013) An evaluation of pomological, morphological and genetic characteristics of some cultivars and genotypes of Iranian apricots. Iran J Hortic Sci 44(2):179–191 (in Farsi)

Molaie S, Soleimani A, Zeinalabedini M, Maleki B (2014) Study of self-incompatibility in some apricot (*Prunus armeniaca* L.) genotypes using classic and molecular methods. Seed Plant Improv J 30(4):777–790 (in Farsi)

Momenpour A, Ebadi A, Imani A (2011) Discrimination of almond self compatible genotypes by different methods in a breeding program in Iran. Afr J Agric Res 6(23):5251–5260

Momenpour A, Imani A, Bakhshi D, Rezaie H (2015) Effect of salinity stress on concentrations of nutrition elements in almond (*Prunus dulcis*) 'Shokofeh', 'Sahand' Cultivars and '13-40' Genotype Budded on GF677 Rootstock. J Hortic Sci 29(2):255–268 (in Farsi)

Mostafavi M (1991) Preliminary study of apricot cultivars in terms of quantity and quality and compatibility determination of cultivars with weather condition. Final report of a research project. Seed and Plant Improvement Research Institute, Karaj, Iran (in Farsi)

Mousavi SA, Fatahi Moghadam MR, Zamani Z, Imani A, Ortega E, Dicenta F (2011) Identification of self-incompatibility alleles in Iranian almond cultivars and genotypes using PCR. Iran J Hortic Sci 42(2):169–183 (in Farsi)

Mousavi SA, Fatahi Moghadam MR, Zamani Z, Tatari M, Imani A, Ortega Pastor E (2014) Identification of self-incompatibility alleles in Iranian almond cultivars using sequencing. Seed Plant Improv J 30(3):651–668 (in Farsi)

Mozaffarian V (2005) Trees and shrubs of Iran. Farhang Moaser Publisher, Tehran, pp 642–664 (in Farsi)

Najafi H, Zeinalabedini M, Majidian P, Dojhampour J, Dabab M (2012) Evaluation of genetic diversity among apricot (*Prunus armeniaca* L.) genotypes using microsatellites markers. J Crop Breed 4(9):68–76 (in Farsi)

Najafzadeh R, Arzani K, Bouzari N, Saei A (2013a) Identification and evaluation of Iranian superior sour cherry genotypes using microsatellite markers (SSR). In: Proceedings of the 8th Iranian congress of horticultural science, Hamadan, Iran, pp 182–187 (in Farsi)

Najafzadeh R, Arzani K, Bouzari N, Saei A (2013b) Evaluation of genetic relationships between iranian superior sour cherries and foreign cultivars using ISSR markers. In: Proceedings of the 8th Iranian congress of horticultural science, Hamadan, Iran, pp 1062–1067 (in Farsi)

Najafzadeh R, Arzani K, Bouzari N (2014) Fruit physicochemical and qualitative characteristics of some superior sour cherry (*Prunus cerasus* L.) genotypes. Seed Plant Improv J 30(3):623–650 (in Farsi)

Nejatian MA (2003) Study on genetic diversity of some local Iranian apricot (*Prunus armeniaca* L.) cultivars. Unpublished PhD thesis, Tarbiat Modarres Univ, Tehran, Iran (in Farsi)

Nejatian MA, Arzani K (2004) Determination of self-incompatibility and effective pollination period in four local Iranian apricots (*Prunus armeniaca* L.) cultivars. Iran J Hortic Sci Technol 5(3):147–156 (in Farsi)

Nejatian MA, Ebadi A (2006) Study on pollen germination and pollen tube growth of eleven apricot cultivars on *in vitro* condition. J Agric Sci Islam Azad Univ 12(1):155–164 (in Farsi)

Nekonam F, Fattahi Moghadam M, Ebadi A (2011) Investigation of incompatibility in four Iranian commercial cultivars of apricot. Iran J Hortic Sci 42:1–9 (In Farsi)

Nikolić D, Milatović D (2010) Examining self-compatibility in plum (*Prunus domestica* L.) by fluorescence microscopy. Genetika 42(2):387–396

Nikoumanesh K, Ebadi A, Zeinalabedini M, Gogorcena Y (2011) Morphological and molecular variability in some Iranian almond genotypes and related *Prunus* species and their potentials for rootstock breeding. Sci Hortic 129(1):108–118

Potter D, Eriksson T, Evans RC, Oh S, Smedmark JEE, Morgan DR, Kerr M, Robertson KR, Arsenault MP, Dickinson TA et al (2007) Phylogeny and classification of Rosaceae. Plant Syst Evol 266:5–43

Rahemi AR (2001) The development of almond orchards in Iran. In: III International symposium on pistachios and almonds. Acta Hortic 591:177–180

Rahemi A, Yadollahi A (2006) Rainfed almond orchards in Iran, ancient and new methods and the value of water harvesting techniques. Acta Hortic 726:449–453

Rahemi A, Fatahi R, Ebadi A, Taghavi T, Hassani D, Gradziel T, Chaparro J (2010) Genetic variation of S-alleles in wild almonds and their related *Prunus* species. Aust J Crop Sci 4(8):648–659

Rahemi A, Fatahi Moghadam MR, Ebadi A, Taghavi T, Hassani D (2011) Fruit characteristics of some wild almonds in Iran. Seed Plant Improv J 27(4):459–481 (in Farsi)

Rahemi A, Fatahi R, Ebadi A, Taghavi T, Hassani D, Gradziel T, Folta K, Chaparro J (2012) Genetic diversity of some wild almonds and related *Prunus* species revealed by SSR and EST-SSR molecular markers. Plant Syst Evol 298(1):173–192

Rahemi A, Fattahi Moghadam MR, Ebadi A, Taghavi T, Hassani D (2013) An evaluation of S-allele amplification in wild almond species and in related species using PCR. Iran J Hortic Sci 44(3):315–328 (in Farsi)

Rahimi Dvin S, Gharaghani A, Eshghi S, Ansari A (2016) Genetic diversity of nut characteristics in some wild almond species in southern Zagros region of Iran. In: International symposium on role of plant genetic resources on reclaiming lands and environment deteriorated by human and natural action, Shiraz University, Shiraz, Iran. Abstract book, p 57

Rahnemoon H (2010) Evaluation of the eight genotypes of apricots native to Azerbaijan to introduce new commercial cultivars. Final report of a research project. Seed and Plant Improvement Research Institute, Karaj, Iran (in Farsi)

Raji MR, Fattahi Moghadam MR, Jannati Zadeh A (2011) Investigation of genetic diversity of peach (P*runus persica*) genotypes using morphological characteristics. In: Proceedings of the 7th Iranian horticultural sciences congress, Isfahan University of Technology, Isfahan, Iran (in Farsi)

Raji R, Jannatizadeh A, Fattahi R, Esfahlani MA (2014) Investigation of variability of apricot (*Prunus armeniaca* L.) using morphological traits and microsatellite markers. Sci Hortic 176:225–231

Ramming DW, Cociu V (1990) Plums. Acta Hortic 290:1–63

Rasouli M, Arzani K (2010) Effect of pollen source on qualitative and quantitative characteristics of sweet cherry (*Prunus avium* L.) fruit cv.'Zard daneshkadea'. Iran J Hortic Sci 41(4):309–318 (in Farsi)

Rasouli M, Arzani K, Eimani A, Moghadam MRF (2010) An investigation of the pollination compatibility of some sweet cherry cultivars on 'Zard Daneshkada'. Iran J Hortic Sci 41(2):143–151 (in Farsi)

Rasouli M, Fattahi Moghadam MR, Zamani Z, Imani A, Ebadi A (2012) In: Proceedings of the 7th Iranian genetics congress, vol 1, pp 89–100 (in Farsi)

Rasouli M, Fattahi Moghadam MR, Zamani Z, Imani A, Ebadi A (2014a) Evaluation of genetic relationships between almond (*Prunus dulcis* L.) cultivars and genotypes using SSR markers. Iran J Hortic Sci 45(2):151–162 (in Farsi)

Rasouli M, Tavakoli R, Imani A, Zarifi E, Majd MA, Martínez-Gómez P (2014b) Cytogenetical analysis of Iranian wild almond species. J Nuts 5(1):63–67 (in Farsi)

Razavi F, Hajilou J, Tabatabaei SJ, Dadpour MR (2011) Comparison of chilling and heat requirement in some peach and apricot cultivars. Res Plant Biol 1(2):40–47(in Farsi)

Rechinger KH (ed) (1963–2001). Flora Iranica. Akademische Drucku, Verlagsanstalt, Graz

Rehder A (1940) Manual of cultivated trees and shrubs, 2nd edn. MacMillan, New York, pp 452–481

Roger DW (1986) Pollen incompatibility groups of sweet cherry clones. J Am Soc Hortic Sci 93:119–123

Sabeti H (1997) Forests, trees and shrubs of Iran. Yazd University Publishers, Yazd, pp 211–225 (in Farsi)

Salunkhe DK, Desai BB (1984) Postharvest biotechnology of fruits. CRC Press, Boca Raton, p 168

Sansavini S, Lugli S (2005) Sweet cherry breeding programs in Europe and Asia. In: 5th international cherry symposium. Acta Hortic 795:41–58

Sedaghathoor S, Ansari R, Allahyari MS, Nasiri E (2009) Comparison of morphological characteristics of some plum and prune cultivars of Iran. Sci Res Essays 4(10):992–996

Seed and Plant Improvement Institute (2016) http://www.spii.ir/spSPII/default.aspx?page=Document&app=Documents&docId=12230&docParId=11469. Accessed 16 June 2016 (in Farsi)

Shahi-Gharahlar A, Zamani Z, Fatahi MR, Bouzari N (2010) Assessment of morphological variation between some Iranian wild *Cerasus* sub-genus genotypes. Hortic Environ Biotechnol 51:308–318

Sheikh-Alian A, Vezvaei A, Ebadi A, Fatahi Moghadam MR, Sarkhosh A (2010) Determination of S-alleles in selected Iranian and foreign cultivars of almond, *Prunus dulcis* Miller [D.A. Webb]. Iran J Hortic Sci 41(3):247–252 (in Farsi)

Shi S, Li J, Sun J, Yu J, Zhou S (2013) Phylogeny and classification of *Prunus* sensu lato (Rosaceae). J Integr Plant Biol 55(11):1069–1079

Shiran B, Amirbakhtiar N, Kiani S, Mohammadi Sh, Sayed-Tabatabaei BE, Moradi H (2007) Molecular characterization and genetic relationship among almond cultivars assessed by RAPD and SSR markers. Sci Hortic 111: 280–292

Shojaee K, Davarynejad G, Nezami A (2012) An Investigation on freezing tolerance of peach and nectarine reproductive buds in controlled conditions. Iran J Hortic Sci 43(1):13–22 (In Farsi)

Socias i Company R (1990) Breeding of self-compatible almonds. Plant Breed Rev 8:313–338

Son L (2010) Determination of quality characteristics of some important Japanese plum (*Prunus salicina* Lindl.) cultivars grown in Mersin–Turkey. Afric J Agric Res 5(10):1144–1146

Sorkheh K, Shiran B, Gradziel TM, Epperson BK, Martínez-Gómez P, Asadi E (2007) Amplified fragment length polymorphism as a tool for molecular characterization of almond germplasm: genetic diversity among cultivated genotypes and related wild species of almond, and its relationships with agronomic traits. Euphytica 156(3):327–344

Sorkheh K, Shiran B, Kiani S, Amirbakhtiar N, Mousavi S, Rouhi V, Mohammady S, Gradziel TM, Malysheva-Otto LV, Martínez-Gómez P (2009a) Discriminating ability of molecular markers and morphological characterization in the establishment of genetic relationships in cultivated genotypes of almond and related wild species. J For Res 20(3):183–194

Sorkheh K, Shiran B, Rouhi V, Asadi E, Jahanbazi H, Moradi H, Gradziel TM, Martínez-Gómez P (2009b) Phenotypic diversity within native Iranian almond (*Prunus* spp.) species and their breeding potential. Genet Resour Crop Evol 56(7):947–961

Sorkheh K, Shiran B, Khodambshi M, Rouhi V, Ercisli S (2011a) In vitro assay of native Iranian almond species (*Prunus* spp.) for drought tolerance. Plant Cell Tissue Organ Cult 105(3):395–404

Sorkheh K, Shiran B, Rouhi V, Khodambashi M (2011b) Influence of temperature on the in vitro pollen germination and pollen tube growth of various native Iranian almonds (*Prunus* L. spp.) species. Trees 25(5):809–822

Stanys V, Stanyte R, Staniene G, Vinskiene J (2008) S-allele identification by PCR analysis in Lithuanian sweet cherries. Biologija 54(1):22–26

Szabó Z (2003) Plum (*Prunus domestica* L.). In: Kosma P, Nyeki J, Soltesz M, Szabo Z (eds) Floral biology, pollination and fertilisation in temperate zone fruit species and grape. Akadémiai Kiado, Budapest, p 383–410

Tehrani G, Browns SK (1992) Pollen-incompatibility and self-compatibility in Sweet Cherry. In: Janick J (ed) Plant Breeding Reviews, vol 9. Wiley, New York, pp 367–388

Valizadeh B, Ershadi A (2009) Identification of self-incompatibility alleles in Iranian almond cultivars by PCR using consensus and allele-specific primers. J Hortic Sci Biotechnol 84(3):285–290

Wöhrmann T, Guicking D, Khoshbakht K, Weising K (2011) Genetic variability in wild populations of *Prunus divaricata* Ledeb. in northern Iran evaluated by EST-SSR and genomic SSR marker analysis. Genet Resour Crop Evol 58(8):1157–1167

Yadollahi A, Arzani K, Ebadi A, Wirthensohn M, Karimi S (2011) The response of different almond genotypes to moderate and severe water stress in order to screen for drought tolerance. Sci Hortic 129(3):403–413

Yildiz F (1994) New technologies in apricot processing. J Stand Apric Spec Issue Ank 67–69

Yilmaz KU, Gurcan K (2012) Genetic diversity in apricot. In: Caliskan M (ed) Genetic diversity in Plants. InTech, Rijeka, pp 249–270

Yousefzadeh K, Houshmand S, Madani B, Martínez Gómez P (2010) Studies in Iranian wild almond species. Caryologia 63(2):117–123

Zamani Z, Imani A, Mousavi A, Fatahi R, Dicenta F, Martínez-Gómez P (2009a) Morphological and molecular characterization of Iranian almond cultivars and their implications for breeding. Acta Hortic 912:601–606

Zamani Z, Khadivi-Khoob A, Boozari N, Jafari HR (2009b) Genetic diversity assessment of some sour and duke cherry genotypes and cultivars using RAPD markers. Iran J Hortic Sci 40(3):1–9 (in Farsi)

Zamani Z, Khadivi-Khoob A, Boozari N, Jafari HR (2009c) An analysis of genetic diversity in some Iranian and foreign sweet cherry (*Prunus avium* L.) cultivars using RAPD molecular marker. Iran J Hortic Sci 40(3):11–20 (in Farsi)

Zamani Z, Shahi-Gharahlar A, Fatahi R, Bouzari N (2012) Genetic relatedness among some wild cherry (*Prunus* subgenus *Cerasus*) genotypes native to Iran assayed by morphological traits and random amplified polymorphic DNA analysis. Plant Syst Evol 298(2):499–509

Zeinalabedini M, Majourhat K, Khayam-Nekoui M, Grigorian V, Torchi M, Dicenta F, Martínez-Gómez P (2008) Comparison of the use of morphological, protein and DNA markers in the genetic characterization of Iranian wild *Prunus* species. Sci Hortic 116:80–88

Zeinalabedini M, Khayam-Nekoui M, Grigorian V, Gradziel TM, Martínez-Gómez P (2010) The origin and dissemination of the cultivated almond as determined by nuclear and chloroplast SSR marker analysis. Sci Hortic 125(4):593–601

Zeinalabedini M, Khayam-Nekoui M, Imani A, Majidian P (2012) Identification of self-compatibility and self-incompatibility genotypes in almond and some *Prunus* species using molecular markers. Seed Plant Improv J 28(2):227–238 (in Farsi)

Zeinalabedini M, Dezhampour J, Majidian P, Khakzad M, Zanjani BM, Soleimani A, Farsi M (2014) Molecular variability and genetic relationship and structure of Iranian *Prunus* rootstocks revealed by SSR and AFLP markers. Sci Hortic 172:258–264

Zokaee-Khosroshahi M, Esna-Ashari M, Ershadi A, Imani A (2014) Morphological changes in response to drought stress in cultivated and wild almond species. Int J Hortic Sci Technol 1(1):79–92