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Almond production experience in Iran compared to other countries in the world

Ali Imani
Temperate Fruits Research Center, Horticultural ,Sciences Research Institute, Agricultural Research Education and Extension Organization (AREEO), Karaj, Iran

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بسم الله الرحمن الرحیم

In The Name of God

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Preface

Almond is one of the most important horticultural crops in Iran due to its unique properties such as high levels in water use efficiency, fruit production, light saturation point, and specific fruit growth curve, osmotic adaptation properties in leaves, special leaf morphology and fruit, alongside with strong and vertical rooting system with enabling it to survive in unfavorable soil conditions such as calcareous and rocky soils with low moisture. That is why the almond is called a drought-tolerant tree. As Iran is located in the arid and semi-arid regions with water shortage, as well as the ease of almond fruit harvesting and transporting for almond employment, this species has long been considered by Iranian growers. Therefore, almond cultivation in Iran has a long history, making it is one of the main centers of almond production in the world. In addition to the considerable area under almond cultivation, there is a potential for extending almond-cultivation areas in Iran. Therefore, developing the planting and production of this crop must be in accordance with its international standards for competition in the global market.

The first step to establishing almond orchards in the country requires knowledge on almond ecological needs, cultivars/ rootstock, and cultivation practices, we hope to help economic prosperity and employment in the country. An effective tool to improve the level of knowledge and skills of growers is through providing scientific resources. For this purpose, the present issue has been compiled based on the scientific and research experiences of its author as well as the collection of scientific resources from leading countries in the field of almond cultivation and production.

would like to thank Dr. Shokrallah Hajivand, Dr. Valiollah Rasoli, Dr. Sadegh Mohajer, Dr. Mansoureh Keshavarzi, Dr.Asghar Mousavi, Engineer Asghar Azizi, Dr.Mojtaba Mohamadizadeh and Dr.Mohammad Rostamian for reading and reviewer this book.

Given the area under cultivation of almond, it is hoped that this issue will be able to compensate for the lack of information in this field and be used by almond growers and experts.

Ali Imani
Spring 2022

Contents

1. Introduction

This booklet reviews the trend of the almond industry in Iran compared to other countries in the world. It also highlights the major challenges in the almond production topics worldwide. Global experiences in overcoming almond production problems and improving almond production process and industry are summarized based on the following topics:

a) Reducing the risk of late spring frost damage by introducing productive, late-flowering cultivars.

b) Increasing fruit set (yield) by incorporating pollination management and self-compatible cultivars.

c) Improving yield qualitatively and quantitatively by introducing cultivars with high-quality fruit and fruitful.

d) Technical knowledge transfer and their dissemination to beneficiaries in increasing output.

1.1. Origin and history of almond

Almond (*Prunus dulcis* (Mill.) D. A. Webb, Syn. *P. amygdalus*) is a native species of Central and West Asia's arid and mild-arid mountainous regions. There are different hypotheses about the origin of domesticated almonds. However, the two hypotheses are more plausible. According to the first hypothesis proposed by Russian scientists, almonds are the result of selection among the species of domesticated almond species *Prunus communis* in its two natural habitats and main origins in Asia including: 1. The foothills of the hot mountainous regions in Central Asia between Iran, Turkmenistan, and Tajikistan; 2. The foothills of the Tian Mountains between Mongolia and Uzbekistan (Socias i Company and Gradziel, 2017).

Many wild almond species and native cultivars are also found in the arid mountainous areas of Central and Western Asia (Imani, 2000). The growth of 19 species of almonds in Iran (Sabeti, 1999), introduces Iran as one of the origins of species, and for this reason, some botanists consider Iran to be the main homeland of almonds (Sabeti, 1999; Rahemi *et al*., 2010).

Proponents of the second hypothesis believe that the domestic almond species, *P. communis*, is the result of numerous natural crossings over time within the wild species of *P. Fenzliana*, *P. bucharica*, and possibly other unknown wild almond species. According to them, the emergence of domesticated almonds coincided with the emergence of ancient human populations (Kester and Gradiziel, 1996, Gradiziel, 2009).

The history of almond cultivation and production dates back to the third millennium BC. About 3200 years ago, the remains of a hard-shelled almond were found by the Sumerians. The early production centers of almond have been traced back to ancient civilizations and ancient trade routes such as the Silk Road. Almonds, along with crops such as grapes, olives, and figs have been developed by early civilizations in Central and Southwest Asia (Kester and Gradiziel, 1996; Gradziel *et al*., 2001). Almonds originated from Central Asia spread around the Mediterranean Sea and then to North and South America, South Africa, and Australia. The wild almond species are found in Central Asia and have a wide morphological diversity. More than 30 species of almond have been introduced by botanists around the world (Kester and Gradiziell 1996; Socias i Company and Gradziel, 2017). Wild almond species often have a bitter kernel due to their high levels of amygdalin. Almonds with the sweet kernel are more likely due to a genetic mutation in different species of almonds (Kester and Asay, 1975; Kester and Gradiziell 1996; Socias i Company, and Gradziel, 2017). The selection of almonds with sweet kernels in wild species by indigenous peoples has been the beginning of the domestication of almonds (Kester and Asay, 1975).

The evolution and distribution of almonds in terms of growing and production, as well as domestication, can be divided into three stages: Asian, Mediterranean, and Californian (Figure 1) (Kester *et al*., 1991; Kester and Gradiziel 1996; Martínez-Gómez *et al*., 2007).

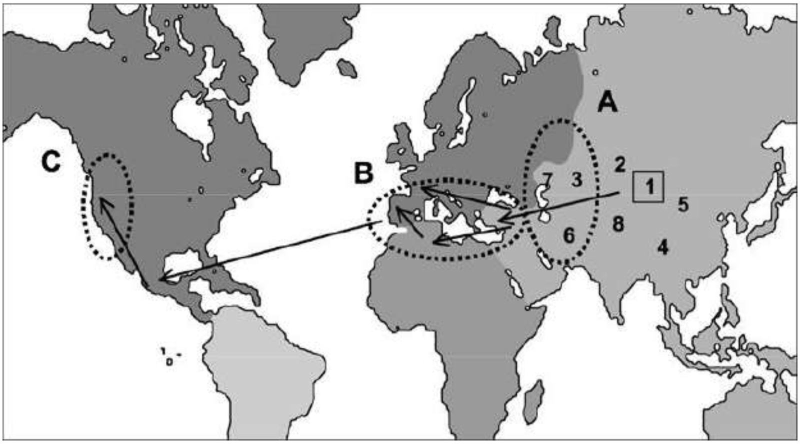


Figure 1. Map of the world showing the origin of almond [*Prunus dulcis*(*1*)], and different relative *Prunus* species [*P. bucharica* (*2*), *P. fenzliana* (*3*), *P. davidiana* (*4*), *P. persica* (*5*), *P. scoparia* (*6*), *P. webbii* (*7*), and *P. argentea* (*8*)], the dissemination routes for the cultivated almond [→], and the three main areas for diversification and cultivation of almonds [Asiatic (*A*), Mediterranean (*B*), and Californian (*C*)] (Martínez-Gómez *et al*., 2007)

Asian Developmental Stage: This stage led to the initial domestication and spread of almonds throughout Central and Southwest Asia. The areas included Iran, Syria, parts of China, India, Turkey, and Palestine **(**Kester and Asay, 1975**)**

Mediterranean Developmental Stage: About 300 BC, almonds were first introduced to Greece from Asia Minor and then gradually to all parts of the Mediterranea such as Italy, southern France, Spain, Portugal, and North Africa. Almond cultivation around the Mediterranean Sea is 2,000 years old. During this time, seeding ecotypes and local cultivars evolved. The establishment of almond seeding orchards has been common in the Mediterranean region for centuries, but over the past 150 years, the selection of local cultivars and their propagation by grafting has become common, so that, today the commercial cultivation of almonds developed in France, Italy, Spain, Portugal, Greece and Tunisia has expanded globally (*Kester* and Gradiziel, *1996*; Browicz and Zohary, 1996; Socias i Company and Gradziel, 2017).

Californian Developmental Stage: This stage began in 1850 with French cultivars and cultivation pattern. This cultivation pattern was initially unsuccessful, but the selection of new cultivars including Nonpareil, I. X. L and Ne Plus Ultra by Hatch, and their graft propagation on compatible rootstocks, along with suitable climatic conditions and optimal management of orchards, led to a significant increase in almond cultivation area and production in California (Kester and Gradiziell 1996). As it is now, California has a large share of global almond production (FAO, 2019).

As mentioned earlier, reports show that today's domestic almonds are the result of numerous crossings that have taken place over time between their wild species (Kester and Asay, 1975; Sabeti, 1999; Rahemi *et al*., 2010). Vavilov (1929), a well-known Russian botanist, believes that today's almonds have three distinct botanical species, *P. bucharica, P. fenzliana,* and *P. ulmifolia* and the current domestic cultivars have evolved through numerous intercrosses between these three species over time. Some botanists believe that the current domesticated almonds are the result of natural hybrids derived from the crossing between two wild species of *P. finzliana*, and *P. bucharica*.

There are about 400 species and seven subspecies of trees and shrubs in the *Prunus* genus. Compared to other genera in the Rosacea family, this genus has more species and domestic cultivars of fruit trees. Almonds are classified in the same genus as cherries, plums, apricots, peaches, and nectarines **(**Kester and Gradiziell 1996**)**. The structure and composition of molecular genetics of almonds are very similar to those of peaches so that they are introduced in the same species, which is confirmed by the absence of crossing barriers and gene entries. Also, cultivated almond cultivars can easily cross with wild almond species, which has led to the creation and expansion of a wide variety of almond morphology and physiology (Rahemi *et al.*, 2010). Thus, as mentioned earlier today, more than 30 species of almonds have been introduced by botanists, some of which appear to be subspecies and ecotypes that have adapted to different environmental conditions **(**Kester and Gradiziell, 1996**)**.

Among 30 almond species identified so far, only the domestic species (*Prunus dulcis*) is important in terms of commercial value and economic production. This is because most commercial cultivars are derived from this species. Other species are often used as shrubs or trees to protect soil, rootstocks, ornamental shrubs, or to transmit resistance genes in breeding programs. As stated above, wild almond species are distributed throughout Central and Western Asia, including China, Tajikistan, Afghanistan, Iran, Turkey, and Syria **(**Kester and Gradiziell, 1996**)**. Although the number of wild almond species has not been established due to the existence of different geographical distances, botanists have divided these wild species into four sections, each of which has a number of species (Table 1).

Table 1. Botanical relationship among species of the genus *Prunus* in the subgenus Amygdalus (Source: Kester and Gradziel, 1996; Gradziel, 2009)

I-**Almond group**
Section Euamygdalus Spach
Prunus dulcis (Miller) D.A. Webb
P. bucharica Korshinsky
P. communis (L) Archangeli
P. fenzliania Fritsch
P. kuramica Korchinsky
P. orientalis (Mill.), syn. P. *argentea* (Lam)
P. kotschyi (Boissier and Hohenm. (Nab) and Rehd.)
P. korschinskii Hand-Mazz.
P. webbii (Spach) Vieh.
P. zabulica Serifimov
Section Spartioides Spach
P. scoparia Spach
P. spartioides Spach
P. arabica Olivier
P. glauca Browicz
Section Lycioides Spach
P. spinosissima Franchet
P. turcomanica Lincz.
Section Chameamygdalus Spach
P. nana (Stock)
P. ledebouriana Schle.
P. petunnikowi Lits.
P. tangutica Batal. (syn. *P. dehiscens*) Koehne
II-Peach group
P. persica (L.) Batsch.
P. mira Koehne
P. davidiana (Carriere) Fransch

P. dulcis (P. amygdalis), as well as *P. fenzliana*, *P. nana (P. tenella)*, *P. bucharica*, *P. kotschyi*, and *P. scoparia*, is 2n = 16, which is the same aspeach *P. persica* (Kester *et al*. 1991).

1.2. History of almond cultivation and production in Iran

Almond cultivation and production in Iran have a very long history, so this country is considered to be one of the oldest regions of almond production (Imani, 1997; Moradi and Mousavi, 1999). The areas under cultivation of this plant are more observed in the center of Iran, which has spread to the south and north of the country. These areas include the provinces of East Azerbaijan, Khorasan, Fars, Chaharmahal and Bakhtiari, Isfahan, Markazi, Yazd, Qazvin, Zanjan, Semnan, Kerman and Alborz (Table 2, Figure 2). Due to the special weather conditions, the northern and southern cities of the country are not suitable for growing almonds.

Table 2. Distribution of almonds in different provinces of Iran

Province	Almond distribution locations
Fars	Abadeh, Estaban, Eghlid, Arsanjan, Jahrom, Khorram Bid, Darab, Sepidan, Shiraz, Fasa, Firoozabad, Kazerun, Marvdasht, Mamasani, Neyriz and Bavanat
Isfahan	Nazanz, Najafabad, Nain, Mobarakeh, Golpayegan, Kashanov Falavarjan, Fereydunshahr, Frieden, Shahreza, Semirom, Khansar, Tiran and Kron, Borkhar and Meimeh, Ardestan and Isfahan
Zanjan	Zanjan, Mahneshan, Khodabandeh, Khorramdareh, Abhar, Ijroud andTarom
Khorasan	Bojnourd, Bardaskan, Birjand, Taybad, Torbat Jam, Torbat Heydariyeh, Jajarm, Chenaran, Sabzevar, Sarakhs, Shirvan, Tabas, Ferdows, Fariman, Ghaen and Quchan
Kerman	Baft, Bardsir, Bam, Rafsanjan, Ravar, Sirjan, Zarand, Shahr Babak, Kerman, Jiroft and Kahnooj, Anar
Sistan and Baluchestan	Zahedan, Khash
Kurdistan	Kamyaran, Bijar, Saqez, Baneh, Marivan, Qorveh and Sanandaj
Mazandaran	Savadkuh

Province	Almond distribution locations
Kermanshah	Harsin, Kermanshah, Kangavar, Paveh, Qasr Shirin, Sahneh, Islamabad, Gilan Gharb, Javanroud, Sarpol Zahab and Songhor
Qazvin	Buin Zahra, Takestan and Qazvin
West Azerbaijan	West Azerbaijan Khoy, Salmas, Mako, Naqadeh, Piranshahr, Sardasht, Mahabad, Buchan, Miandoab, Shahin Dej, Oshnoyeh and Urmia
Ardabil	Namin, Kowsar, Ardabil, Meshkinshahr
Hamedan	Bahar, Asadabad, Razan, Aghtar Pigeon, Tuyserkan, Malayer and Nahavand, Hameda
Qom	Qom
Yazd	Ardakan, Abar Kooh, Bafgh, Taft, Mehriz, Sadough and Herat
Markazi	Ashtian, Arak, Tafresh, Khomein, Delijan, Saveh, Shazand and Mahallat
East Azarbaijan	Azarshahr, Osko, Ahar, Bostan Abad, Bonab, Tabriz, Jolfa, Sarab, Shabestar, Kalibar, Maragheh, Marand, Miyaneh, Malekan, Harris, and Hashtrood
Lorestan	Boroujerd, Khorramabad and Doorod
Chaharmahal va Bakhtiari	Farsan, Borujen, Lordegan, Saman and Goharang
Hormozgan	Hajiabad
Tehran	Damavand, Karaj, Savojbolagh, Shahriar, Islamshahr and Shemiranat
Khuzestan	Izeh

As shown in Table 2, almond distribution is very widespread in the country, and apart from Hormozgan and Golestan provinces, is available in other provinces in irrigated and non-irrigated forms.

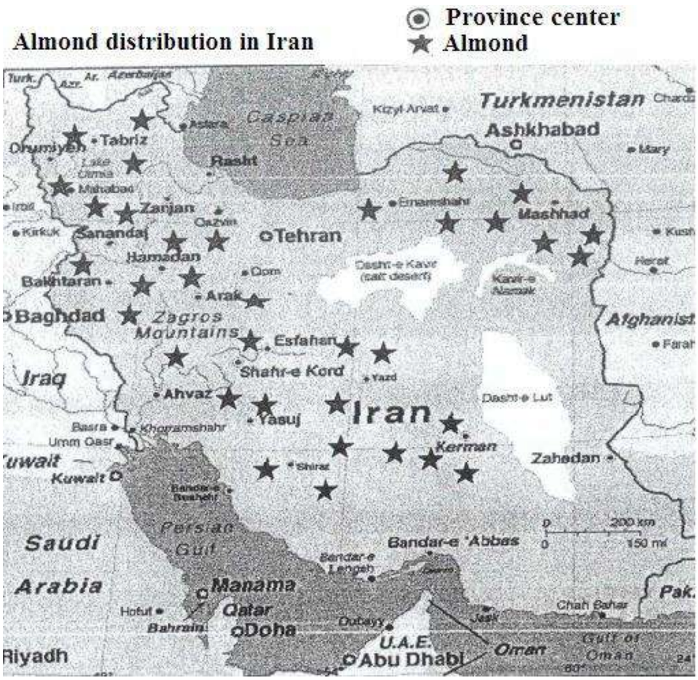


Figure 2. Almond distribution map in Iran

The distribution of almond commercial orchards and major producing sites in Iran is seen in Figure 3.

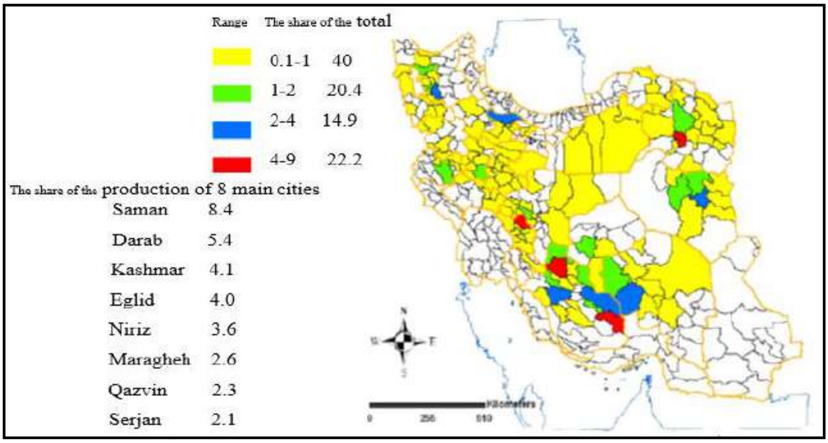


Figure 3. Distribution of almond commercial orchards and major almond-producing sites in Iran (Deputy of Horticulture, Ministry of Jihad e Agriculture, 2017, www.maj.ir).

1.3. Iran's wild almond germplasm

In general, wild almonds currently account for about 30-40 species (Rahemi, 2010). Most of these almonds originated in Central and Western Asia (Kester and Gradziel, 1996), and Iran is a rich source of this germplasm (Vezvaei, 2003). So far, many of the local almond species have been identified including 22 wild almond species and 7 interspecies hybrids, some of which are native to Iran (Rahemi, 2010). These species are a rich genetic source for desirable characteristics such as resistance to biotic (pests and diseases) and abiotic (drought, winter, and spring frosts) stresses and some of them have characteristics such as low growth, late flowering, self-compatibility, and early fruiting, which have been successfully used in breeding programs (Martinez-Gómez et al., 2005; Gradziel *et al.*, 2001, 2009). According to studies and research conducted by Iranian botanists, there are more than 22 wild almond species in Iran. These species have been identified and reported in the highlands of East and West Azarbaijan, Kurdistan, Kermanshah, Lorestan, Tehran, Fars, Chaharmahal and Bakhtiari, Isfahan, Kohkiluyeh and Boyer-Ahmad provinces, Sistan and Baluchestan, and Tehran (Rahemi *et al.*, 2010). The distribution and fruit characteristics of some wild almond species in Iran are presented in Tables 3, 4, 5, and Figure 4.

Table 3. Wild almonds (*Prunusspp*.) collected from different provinces of Iran (Rahemi *et al.*, 2010)

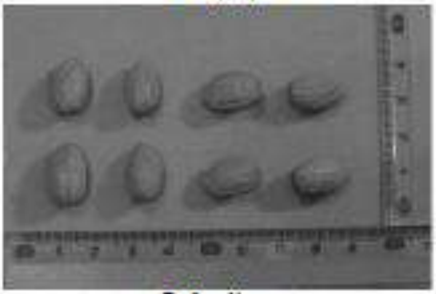
No.	Accession No.	Species	Province	Area
1	1	*P. eburnea*	Isfahan	Feridoonshahr
2	31	*P. eburnea*	West Azarbaijan	Mohabad
3	58	*P. eburnea*	Kerman	Sirjan
4	72	*P. eburnea*	Khorasan	Kalatenaderi
5	94	*P. eburnea*	Fars	Firoozabad
6	42	*P. eburnea*	Kordestan	Kamyaran
7-8	70,71	*P. eburnea*	Khorasan	Kalatenaderi
9	73	*P. eburnea*	Tehran	Tehran
10	7	*P. elaegnifolia*	Isfahan	Semirom
11	43	*P. elaegnifolia*	Kordestan	Kamyaran
12	56	*P. elaegnifolia*	Fars	Darab
13-14	60,61	*P. elaegnifolia*	Kerman	Sirjan
15	64	*P. elaegnifolia*	Fars	Darab
16	96	*P. elaegnifolia*	Fars	Firoozabad
17	95	*P. erioclada*	Fars	Bavanat
18-19	27,35	*P. fenzliana*	West Azarbaijan	Urmieh
20	53	*P. fenzliana*	West Azarbaijan	Makoo
21-22	62,63	*P. hauskonechtii*	Kordestan	Marivan
23	40	*P. hauskonechtii* (var. *pubescence*)	Kordestan	Sanandaj
24-30	21-26,36	*P. korshinski*	West Azarbaijan	Orumieh
31	30	*P. kotschii*	West Azarbaijan	Orumieh

No.	Accession No.	Species	Province	Area
32	8	*P. lycioides*	Isfahan	Kashan
33	55	*P. lycioides*	Fars	Niriz
34	83	*P. lycioides*	West Azarbaijan	Kamyaran
35	86	*P. lycioides*	Chaharmahal va Bakhtiari	Farsan
36-37	13,20	*P. lycioides* (var. *horrida*)	Fars	Niriz
38	34	*P. nairica*	West Azarbaijan	Oshnavieh
39-40	39,52	*P. nairica*	Kordestan	Sanandaj
41-43	2-4	*P. orientalis*	Isfahan	Feridoonshahr
44	45	*P. pabotti*	Kordestan	Kamyaran
45	46	*P. pabotti*	Kordestan	Kamyaran
46	5	*P. scoparia*	Isfahan	Fooladshahr
47	6	*P. scoparia*	Isfahan	Naein
48	14	*P. scoparia*	Fars	Niriz
49	57	*P. scoparia*	Kerman	Urzoeieh
50	65	*P. scoparia*	Fars	Darab
51	87	*P. scoparia*	Chaharmahal va Bakhtiari	Lordegan
52	93	*P. scoparia*	Fars	Firoozabad
53	78	*P. spartioides*	Tehran	Tehran
54	97	*P. spartioides*	Fars	Firoozabad
55	54	*P.* spp.	Yazd	Mehriz
56	59	*P.* spp.	Kerman	Sirjan

P. eburnea

P. elaeagnifolia

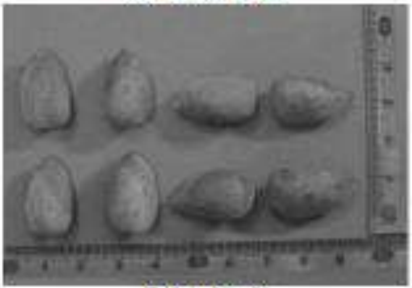
P. erioclada



P. fenzliana

P. hauskonechtii

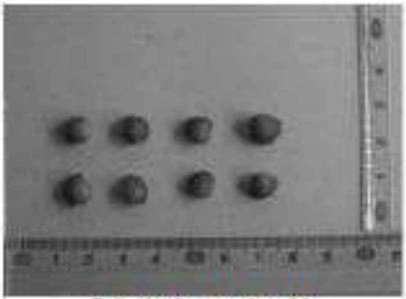
P. hauskonechtii var. *pubescence*



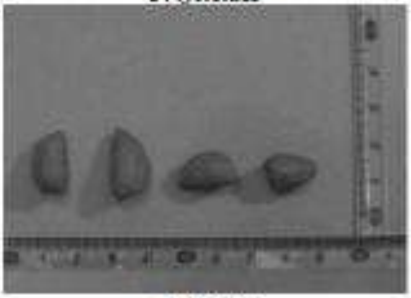
P. korshinski

P. kotschii

P. lycioides



P. lycioides var. *horrida*



P. nairica

P. orientalis

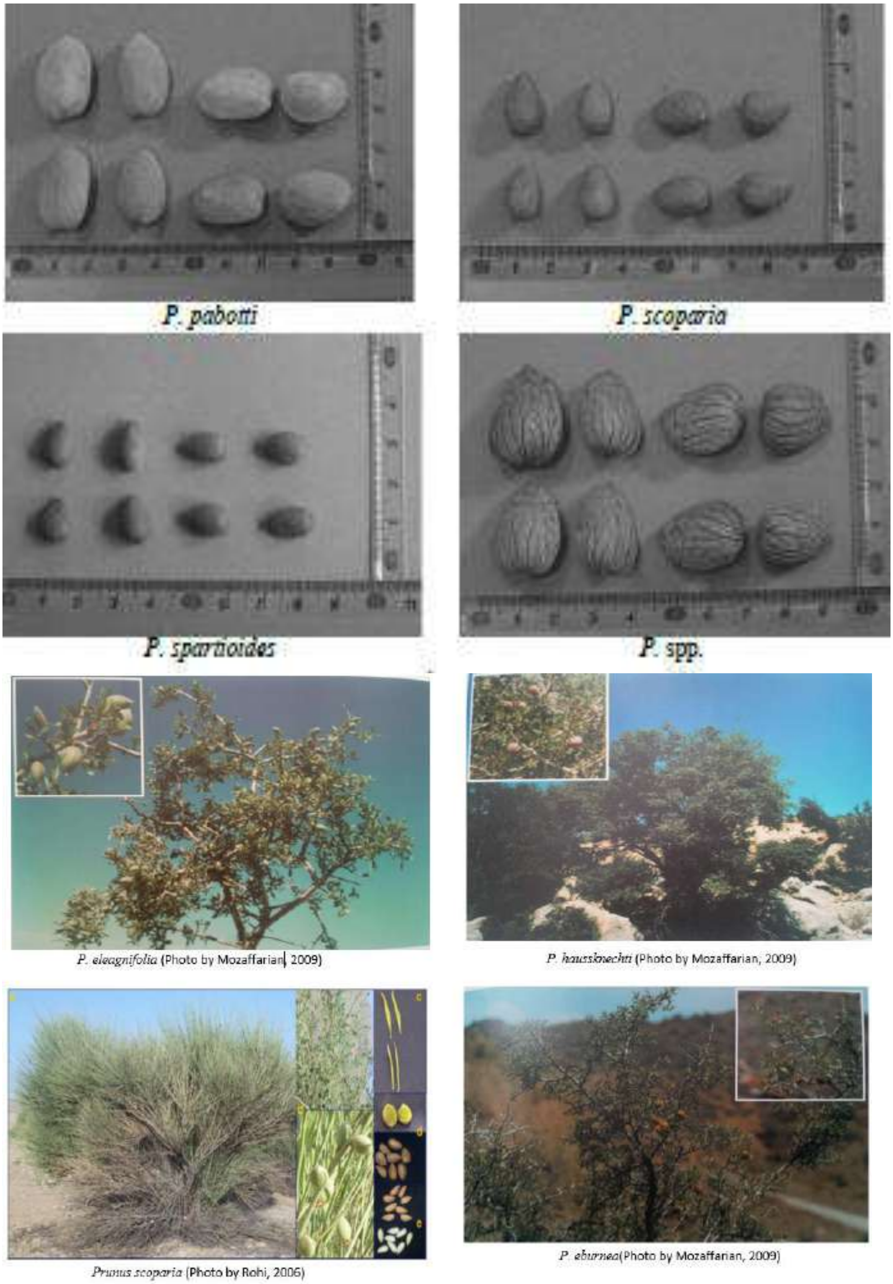


Figure 4. Fruit and tree/shrub characteristics of some wild almond species in Iran (Rahemi *et al.*, 2010)

Table 4. Nut characteristics of wild almond species collected from different areas of Iran (Rahemi *et al.*, 2010)

Species	Nut length (mm)	Nut width (mm)	Nut width/length	Nut thickness (mm)	Nut weight (g)
P. eburnea	14.5±0.12	10.8±0.10	0.75±0.0028	7.6±0.05	0.53±0.0107
P. eburnea Ovate	12.0±0.09	10.8±0.06	0.91±0.0083	7.9±0.03	0.37±0.0057
P. elaegnifolia	16.9±0.09	10.9±0.05	0.65±0.0040	8.1±0.06	0.69±0.0073
P. erioclada	14.6±0.18	11.0±0.17	0.76±0.0119	7.6±0.10	0.58±0.0278
P. fenzliana	18.2±0.29	12.4±0.14	0.69±0.0087	8.1±0.11	0.73±0.0268
P. hauskonechtii	24.7±0.58	15.7±0.32	0.64±0.0033	9.9±0.09	1.81±0.0925
P. hauskonechtii Pub.	24.0±0.46	15.1±0.25	0.63±0.0018	9.0±0.18	1.28±0.1292
P. korshinski	22.4±0.15	13.1±0.05	0.59±0.0038	8.5±0.04	1.12±0.0099
P. kotschii	16.3±0.06	11.4±0.11	0.70±0.0074	10.1±0.08	0.93±0.0196
P. lycioides	14.5±0.22	10.9±0.13	0.77±0.0078	7.4±0.09	0.58±0.0189
P. lycioides Horrida	10.2±0.09	9.1±0.34	0.90±0.0269	7.8±0.05	0.23±0.0281
P. nairica	14.7±0.29	10.4±0.12	0.73±0.0180	7.4±0.05	0.36±0.0118
P. orientalis	17.6±0.22	12.1±0.09	0.69±0.0069	7.1±0.08	0.66±0.0132
P. pabotti	19.3±0.45	13.5±0.19	0.71±0.0093	9.1±0.09	1.13±0.0224
P. scoparia	13.3±0.13	8.8±0.07	0.67±0.0035	7.1±0.04	0.40±0.0078
P. spartioides	16.5±0.12	9.8±0.11	0.60±0.0096	8.9±1.05	0.52±0.0054
P. spp.	21.5±0.30	15.3±0.34	0.71±0.0065	11.1±0.12	1.53±0.0559
Mean	16.8	11.5	0.71	8.1	0.73

± Standard error

Table 5. Kernel characteristics of wild almond species collected from different areas of Iran (Rahemi *et al.*, 2010)

Species	Kernel length (mm)	kernel width (mm)	Kernel width/length	Kernel thickness (mm)	Kernel weight (g)
P. eburnea	11.8±0.07	7.2±0.04	0.61±0.0041	4.8±0.03	0.18±0.0022
P. eburnea Ovate	9.2±0.08	6.5±0.06	0.71±0.0064	3.9±0.09	0.09±0.0039
P. elaegnifolia	13.4±0.07	6.8±0.03	0.51±0.0034	4.9±0.05	0.20±0.0032
P. erioclada	10.8±0.21	6.7±0.10	0.62±0.0128	4.4±0.08	0.15±0.0073
P. fenzliana	12.9±0.16	6.8±0.09	0.53±0.0051	4.3±0.10	0.21±0.0139
P. hauskonechtii	19.0±0.78	10.3±0.22	0.57±0.0235	4.7±0.05	0.44±0.0191
*P. hauskonechtii*Pub.	15.5±0.90	8.4±0.56	0.54±0.0085	2.2±0.58	0.12±0.0560
P. korshinskyi	17.2±0.12	7.7±0.04	0.46±0.0032	4.8±0.03	0.31±0.0034
P. kotschii	12.5±0.18	6.5±0.22	0.52±0.0114	3.8±0.13	0.14±0.0076
P. lycioides	11.5±0.17	7.0±0.08	0.62±0.0067	4.1±0.05	0.13±0.0044
*P. lycioides*Horrida	7.3±0.29	4.2±0.14	0.57±0.0124	2.8±0.21	0.03±0.0053
P. nairica	11.6±0.21	6.4±0.05	0.56±0.0109	3.7±0.15	0.08±0.0033
P. orientalis	13.7±0.19	8.1±0.05	0.60±0.0076	4.5±0.09	0.22±0.0041
P. pabotti	16.0±0.32	8.5±0.06	0.54±0.0092	4.8±0.09	0.32±0.0031
P. scoparia	10.5±0.08	6.0±0.04	0.57±0.0034	4.4±0.02	0.14±0.0025
P. spartioides	13.2±0.10	6.7±0.11	0.51±0.0104	4.5±0.09	0.19±0.0044
P. spp.	16.3±0.21	9.9±0.25	0.61±0.0093	5.8±0.26	0.42±0.0239
Mean	13.0	7.1	0.57	4.4	0.20

± Standard error

1.4. Almond advantages

Almonds, like other nut crops such as walnuts and pistachios, have a very high nutritional value and are very important in the food diet. This nut crop is also important in the pharmaceutical and health industries due to its various beneficial products (Schirra, 1977; Abaspour *et al.*, 2012). Ease of storage, transportation, and non-corruption in normal conditions are other advantages considered by the almond producers. Considering other characteristics as an adaptation to climatic conditions of arid and semi-arid regions, ability to grow in weak and calcareous soils, high water efficiency, long-term storage capacity, ease of transportation and packaging, and long history of cultivation and familiarity of growers with almond cultivation, it can be proposed as one of the best options for orchard establishment in many regions of Iran (Imani and Zeinalabedini, 2019). Regardless of the nutritional value of almonds mentioned above, this nut crop is also very important in terms of the economy and job creation. It increases the revenue of the farmer from the land by about 10 times as much as cereals and creates significant employment (Varmziari *et al.*, 2011).

1.5. Area harvested, production and yield of almonds in the world and different continents

1.5.1. Continents

Reports show that the production and area harvested of almond in the world is concentrated in certain areas, so that the cultivation of the irrigated and rainfed almonds takes place in all suitable areas between the latitudes of 30-55 degrees north (Figure 1).

Major areas of almond production in the world are A) the United States of America, especially the central plains of California; B) Mediterranean countries including European countries such as Spain, Italy, Portugal and Greece, as well as countries in North Africa including Morocco, Algeria, Tunisia, and Libya, which together account for about 20% of global almond production. Among these countries, Spain has the highest area harvested and the second-largest almond producer in the world.

C) Countries in Central and Southwest Asia of the ancient continent: these countries which include Iran, Syria, Turkey, China, Afghanistan, Pakistan, Uzbekistan, Tajikistan, Kyrgyzstan and others, are the world's third-largest producers of almonds, with Iran ranking third after the United States and Spain (FAO, 2019).

According to statistics provided by the World Food Organization (FAO, 2019), the area under cultivation, production and yield of almonds in the world and different continents in 2019 is shown in Table 6. As it is known, out of the total world production of 3497148 tons, the area harvested (2126304 ha) and yielded (1644.7 kg/ha). The Americas are the first for almond production (1976640 tons) with an area harvested (486858 ha), followed by the highest cultivated areas in the continents of Asia (280219 ha) with 599285 tons, Europe (798116 ha) with 476634 tons, Africa (523208ha) with 298179 tons, and Oceania (146410 tons) with an area harvested (37903 ha) (Table 6).

Table 6. Area harvested, production and yield of almonds on each continent in 2019

Area	Production(tons)	Area harvested(ha)	Yield(kg/ha)
world	3497148	2126304	1644.7
Africa	298179	523208	569.9
Americas	1976640	486858	4060.0
Asia	599285	280219	2138.6
Europe	476634	798116	597.2
Oceania	146410	37903	3862.8

1.5.2. Area harvested, production, and yield of almonds in various countries around the world

Almond cultivation is also common in parts of South Africa, South America (Chile, Argentina, etc.) and Australia. In recent years, some countries such as Australia, have also started cultivating and producing almonds, and are rapidly increasing the area harvested and production of almonds using a working method and technology close to the United States. As a result, it produced 72900 tons and 146410 tons in 2016 and 2019, respectively. Today, different cultivars of almonds are grown in different countries around the world (FAO, 2019) (Table 7).

Table 7. Area harvested, production and yield of almonds in various countries in year 2019

Row	Area	Production (tons) 2019	Area harvested (ha)	Yield (kg/ha)
1	Afghanistan	38205	29203	1308.3
2	Algeria	72412	35380	2046.7
3	Argentina	812	434	1871.0
4	Australia	146410	37903	3862.8
5	Azerbaijan	916	574	1595.8
6	Bosnia and Herzegovina	84	312	2692
7	Bulgaria	720	1010	7129
8	Burkina Faso	2077	3691	5627
9	Chile	38950	8867	43927
10	China	45000	12811	35126
11	China, mainland	45000	12811	35126
12	Côte d'Ivoire	2032	3291	6174
13	Croatia	250	620	4032
14	Cyprus	340	2710	1255
15	Eswatini	1052	649	16210
16	France	1130	1180	9576
17	Georgia	925	925	10000
18	Greece	21950	15130	14508
19	Hungary	130	310	4194
20	Iran (Islamic Republic of)	177015	79597	22239
21	Iraq	454	309	14693
22	Israel	10006	473	211543
23	Italy	77300	52040	14854
24	Jordan	1409	363	38815
25	Kazakhstan	85	106	8019
26	Kyrgyzstan	1812	506	35810
27	Lebanon	30887	5086	60729

Row	Area	Production (tons) 2019	Area harvested (ha)	Yield (kg/ha)
28	Libya	38421	64132	5991
29	Mexico	38	27	14074
30	Morocco	102185	190612	5361
31	Nepal	9	23	3913
32	North Macedonia	568	372	15269
33	Pakistan	19994	9602	20823
34	Palestine	3902	2311	16884
35	Portugal	33550	39640	8464
36	Republic of Moldova	532	272	19559
37	Spain	340420	687230	4954
38	Syrian Arab Republic	80258	71520	11222
39	Tajikistan	3270	4446	7355
40	Tunisia	80000	225453	3548
41	Turkey	150000	47088	31855
42	Turkmenistan	1077	1605	6710
43	United Arab Emirates	970	1476	6572
44	United States of America	1936840	477530	40560
45	Uzbekistan	21411	3011	71109
46	Yemen	11340	6474	17516

1.5.3. Area harvested, production, and yield of almonds in the top producing countries

1.5.3.1 Area harvested

According to FAO statistics (2019), Spain, the United States, Tunisia, Morocco, and Iran have the highest almond-harvested areas with 687230, 477530, 225453, 190612 and 79597 hectares, respectively. Other countries including Syria (71520 ha), Italy (52040 ha), Turkey (47088ha), Australia (37903 ha), and Algeria (35380 ha) were categorized in the subsequent class of areas allocated to almond cultivation (Figure 5).

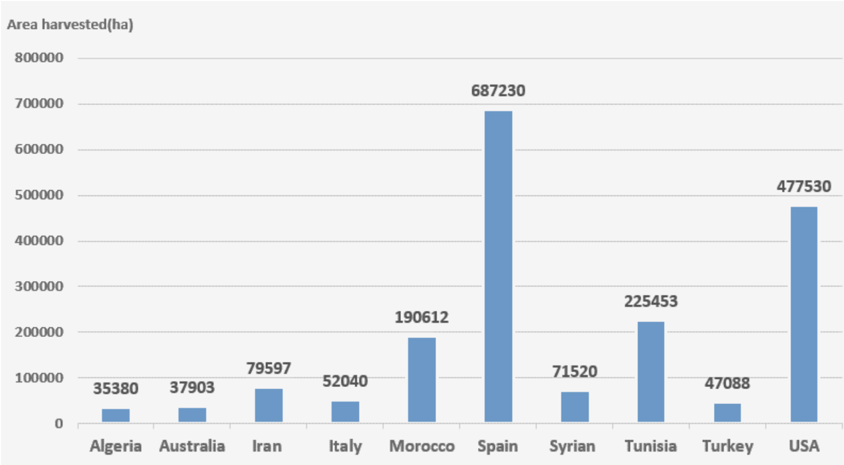


Figure 5. Area harvested of almond in 10 top countries of world in year 2019

1.5.3.2 Production

According to FAO statistics (2019), the United States, Spain, Iran, Turkey, Australia, Morocco, Syria, Tunisia, Italy and Algeria have the highest production with 1936840, 340420, 177015, 150000, 146410, 102185, 80258, 80000, 77300 and 72412 tons, respectively (Figure 6).

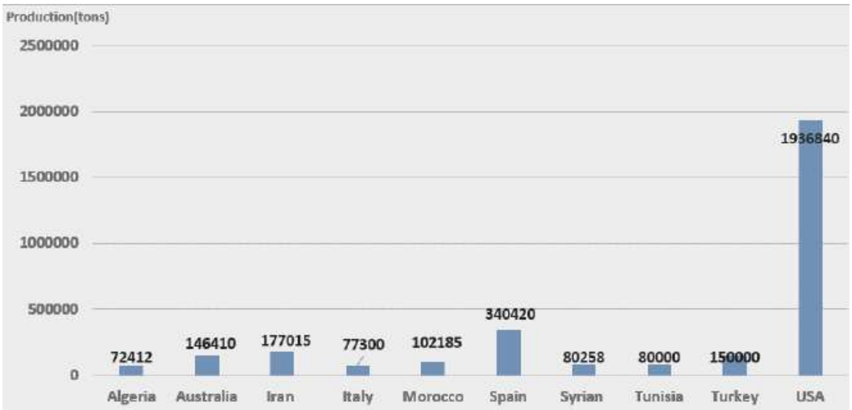


Figure 6. Production of almond in 10 top countries of world in year 2019

1.5.3.3. Yield

Among the 10 top almond producing countries in the world in year 2019, the United States accounted for the highest yield with 4056.0 kg/ha. In second and third places were Australia (3862.8 kg/ha) and Turkey (3185.5 kg/ha). Other countries including Iran (2223.9 kg/ha), Algeria (2046.7k/ha), Italy (1485.4 kg/ha), Syria (1122.2 kg/ha), Morocco (536.1 kg/ha), Spain (495.4 kg/ha) and Tunisia (354.8 kg/ha), were categorized in the in the second category, due to their old crops, rainfed crops and traditional orchard management (Figure 7).

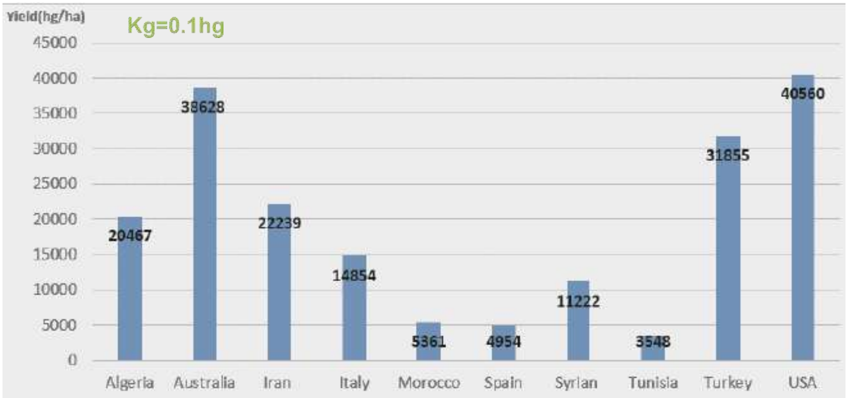


Figure 7. Almond yield in 10 top countries of the world in year 2019

1.6. Almond nut trade on a global scale

1.6.1. Continents

1.6.1.1. Exporters of shelled almonds by continent

According to statistics provided by the Food Agriculture Organization (FAO), the export value (1000 US$) and export quantity (ton) of shelled almonds in the world in 2019 was equivalent to 5994456 and 901764, respectively (Table 8). As it is known, the Americas with export value (3761524000 US$) and export quantity (581622 tons) are followed by the highest shelled almond exports in the continents of Europe (1367712,000 US$) with 189096 tons, Asia (568182000 US$) with 87035 tons, Oceania (290928000 US$) with 42782 tons and Africa (6110000 US$) with 1229 tons.

Table 8. Export value and quantity of shelled almonds in the world and different continents in the year 2019

Area	Export value (1000 US$)	Export quantity (ton)
World	5994456	901764
Africa	6110	1229
Americas	3761524	581622
Asia	568182	87035
Europe	1367712	189096
Oceania	290928	42782

1.6.1.2. Importers of shelled almonds by continent

The import value and quantity of shelled almonds in the world in 2019 were equivalent to 5612449000 US$ and 842961tons, respectively (Table 9). As it is known, out of the total world shelled almond imports, Europe leads with its import value (3003687000 US$) and import quantity (460446 tons) of shelled almonds, followed by the continents of Asia (1929362000 US$) with 288317 tons, the Americas (483786000 US$) with 66166 tons, Africa (149023000 US$) with 21355 tons and Oceania (46591000US$) with 6677 tons.

Table 9. Import value and quantity of shelled almonds in the world and different continents in the year 2019

Row	Area	Import value (1000 US$)	Import quantity (ton)
1	World	5612449	842961
2	Africa	149023	21355
3	Americas	483786	66166
4	Asia	1929362	288317
5	Europe	3003687	460446
6	Oceania	46591	6677

1.6.1.3. With shell almonds exporters by continents

According to statistics provided by FAO, the export value (1000 US$) and quantity (ton) of shelled almonds in the world in year 2019 were equivalent to 1507745 and 330663, respectively (Table 10). As it is known, out of the total world shelled almond export, the Americas with export value (1046189000 US$) and export quantity (215128ton) followed by the highest shelled almond export in the continents of Oceania (246215000 US$) with 48079 tons, Asia (154422000 US$) with 43653 tons, Europe (57071000 US$) with 21631 tons and Africa (3848000 US$) with 2172 tons.

Table 10. Export value and quantity of shelled almonds in the world and different continents in the year 2019

Row	Area	Export value (1000 US$)	Export quantity (ton)
1	World	1507745	330663
2	Africa	3848	2172
3	Americas	1046189	215128
4	Asia	154422	43653
5	Europe	57071	21631
6	Oceania	246215	48079

1.6.1.4. With shell almonds importers by continents

With shell almonds imported by the world were 334683 tons worth US$1555575000 during 2019. From a continental perspective, Asia imported the highest with shell almonds (297556 tons) by highest dollar worth of in-shell almonds (1418439000 US$) shipped during 2019. European importers came in second at 26382 tons with an import value of (78848000), followed by the Americas (7843 tons) with imports valued at 50090000 US$, Africa (2369 tons) with imports valued at 50090000 US$, and Oceania (533 tons) with imports valued at 2783000 US$ with shell almonds (Table 11).

Table 11. Export value and quantity of shelled almonds in the world and different continents in the year 2019

Row	Area	Export value (1000 US$)	Export quantity (ton)
1	World	1555575	334683
2	Africa	5415	2369
3	Americas	50090	7843
4	Asia	1418439	297556
5	Europe	78848	26382
6	Oceania	2783	533

1.6.2. Ten top countries

1.6.2.1. Shelled almonds exporters by country

According to the FAO (2019), the value export and export quantity of shelled almonds is shown in Figures 8-9. So, the United States, Spain, and Australia have the highest shelled almond export quantities with 571361, 107340, and 42751 tons, respectively (Figure 8). Anyway, Iran's shelled almond export quantity (3804 tons) is in the low place.

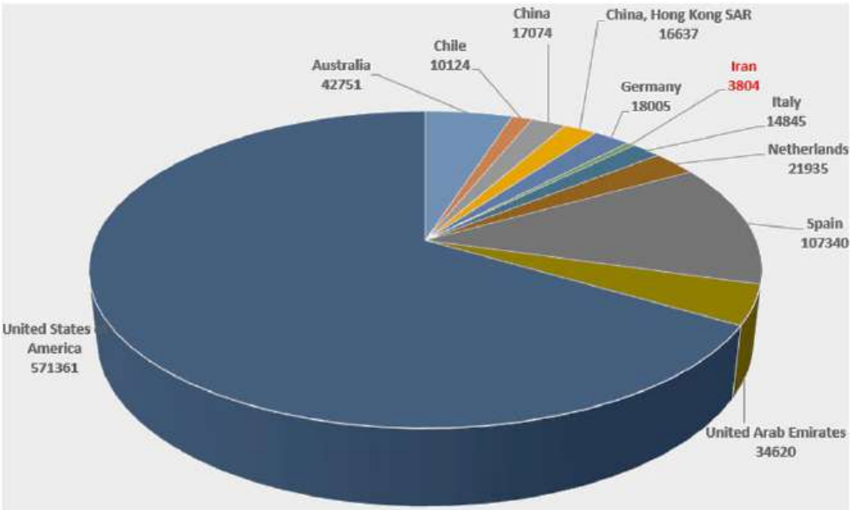


Figure 8. Top shelled almonds (ton) exporters by country in the year 2019

According to the FAO (2019) report, the United States, Spain, and Australia have the highest shelled almond export values with 3687255000, 290704000, and 4770436000 US$ (Figure 9) respectively. Meanwhile, Iran (export value of 8642000 US$) does not have a high position among the exporter countries. Of course, the reason for this can be partly related to high domestic consumption.

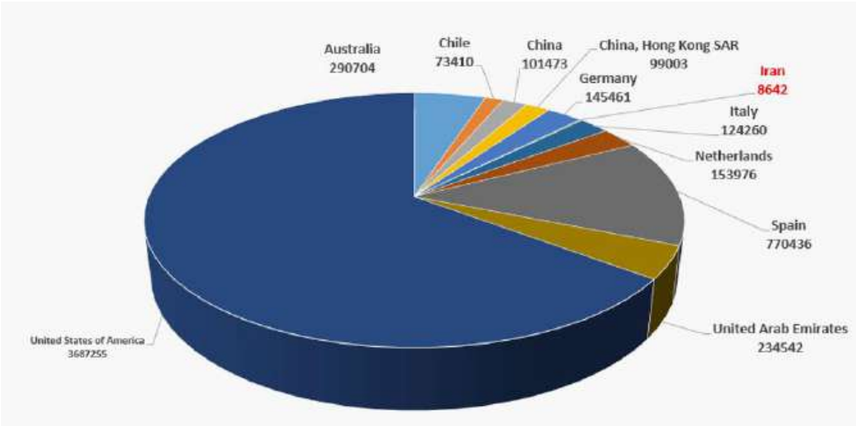


Figure 9. Top shelled almonds (1000 US$) exporters by country in the year 2019

1.6.2.2. Shelled almonds importers by country

Among countries, Germany accounted for the highest dollar worth of imported shelled almonds during 2019 with shipments valued at 669377000 US$ with 101167 tons of the global total. In the second place, Spain's importers were at 535482000 US$ with 93648 tons followed by Italy at 351902000 US$ with 54454 tons. Among the countries importing almond kernels, Iran has allocated 18951 tons of shelled almonds worth1555582 US$. Below, figures 10 and 11 show the 20 countries that exported the highest dollar value of shelled almonds during 2019.

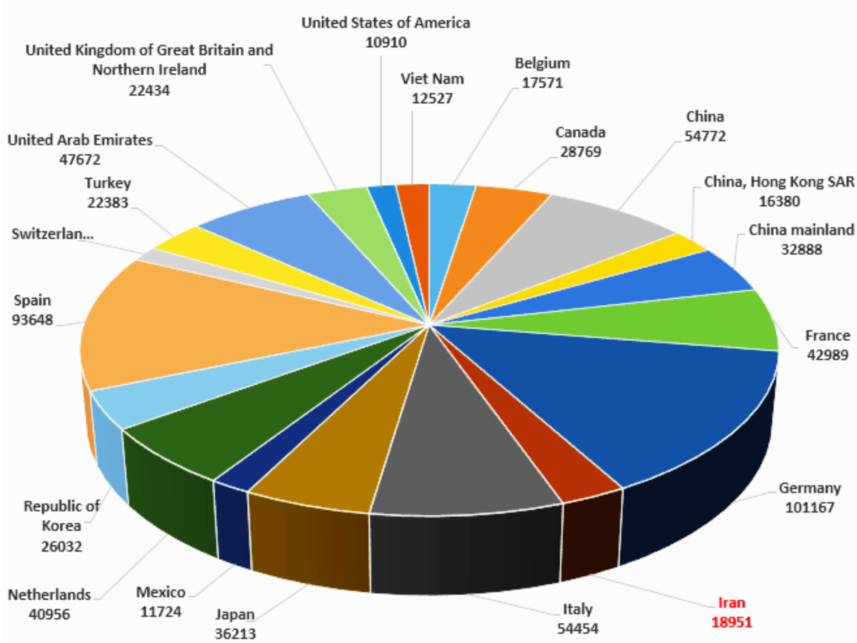


Figure 10. Top shelled almonds (ton) importers by country in the year 2019

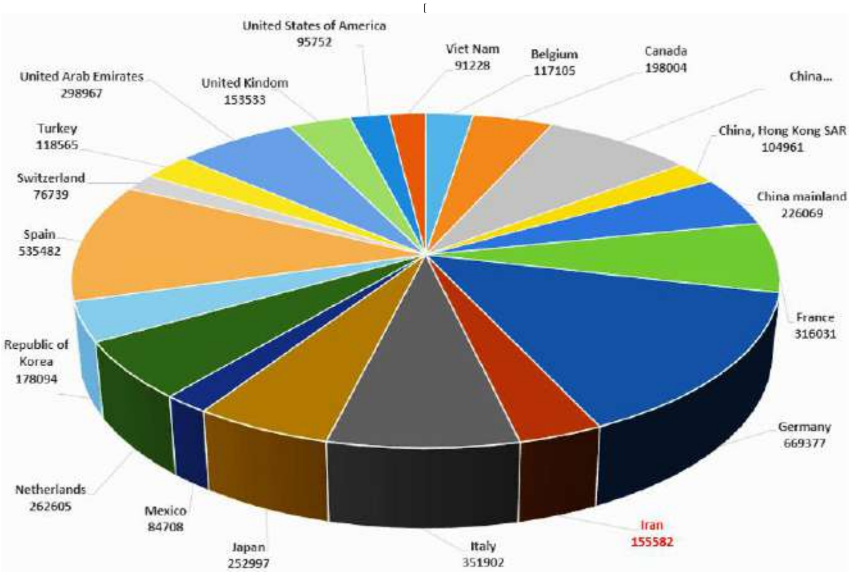


Figure 11. Top shelled almonds (1000 US$) importers by country in the year 2019

1.6.2.3. With shell almonds exporters by country

According to the FAO database (2019), the value of export quantity of shelled almonds is shown in Figures 12-13. So that, the United States (214512 tons), Australia (48069 tons), China (26915 tons), China, Hong Kong SAR (26732 tons), Portugal (14496 tons), United Arab Emirates (8377 tons) and Spain (5498 tons) have the highest with shell almond export quantity (Figure12).

The United States (104212000 US$), Australia (246196000 US$), China, Hong Kong SAR (93393 US$), China (30497000 US$), United Arab Emirates (40258000 US$), Portugal (30497000 US$) and Spain (18856000 US$) have the highest with shell almond export value (Figure 13), respectively. Iran, meanwhile, ranks very low with 67 tons of with shell almonds worth US$ 169000 (Figure12).

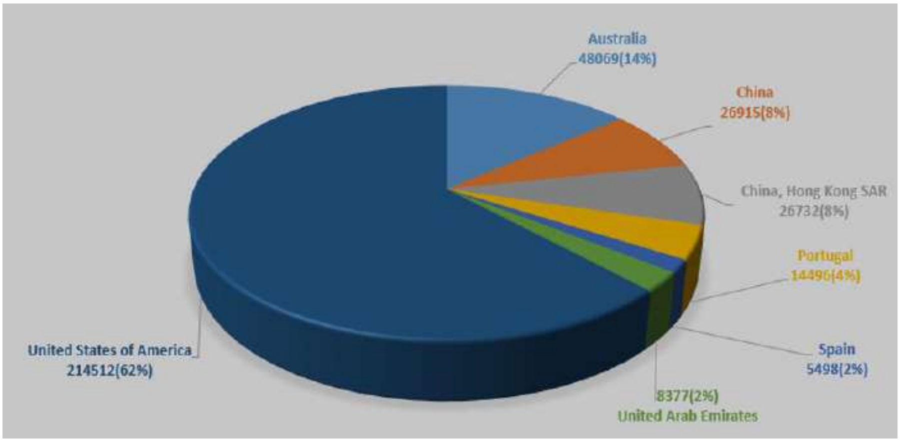


Figure 12. Top with shell almonds (ton) exporters by country in the year 2019

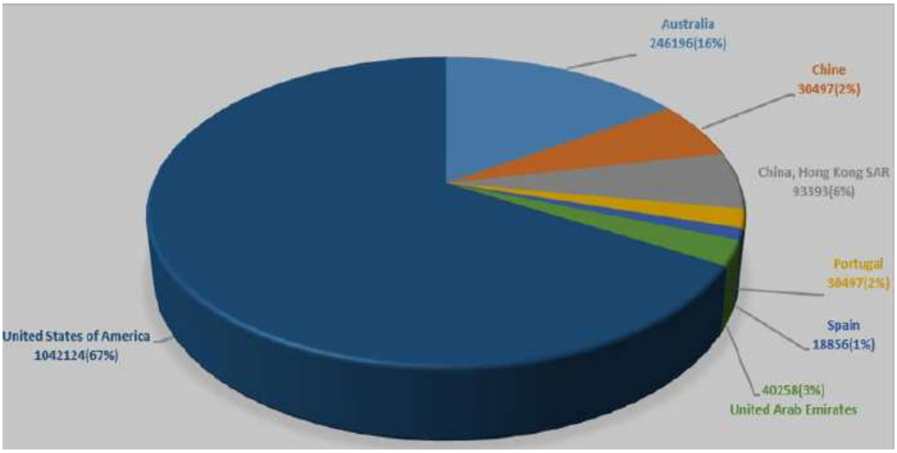


Figure 13. Top with shell almonds (1000 US$) exporters by country in year 2019

1.6.2.4. With shell almonds importers by century

According to the same FAO report, India has the highest with shell almond importers (161652 tons) with an import value of 3687255000 US$. In second place were China importers at 90465 tons with an import value of 802881000 US$ followed by China mainland with 63496 tons with an import value of 299315000 US$ (Figure 14).

Despite the fact that Iran was a good producer of almonds in 2019, it was in the category of imported countries with an import of 5167 tons (1%) of with shell almonds worth US$ 29218 (2%) (Figure 15). As previously announced, this is due to the high domestic consumption of almonds and the informal trade of this product.

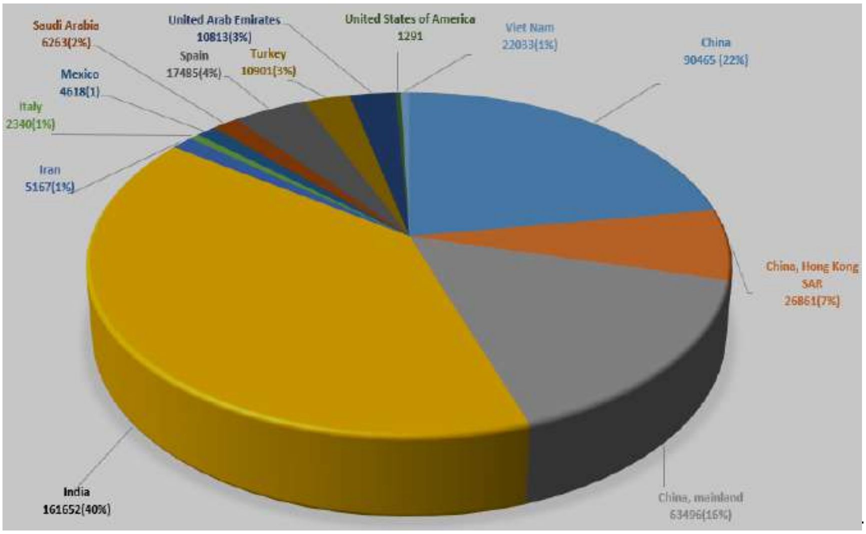


Figure 14. Top with shell almonds (ton) importers by country in the year 2019

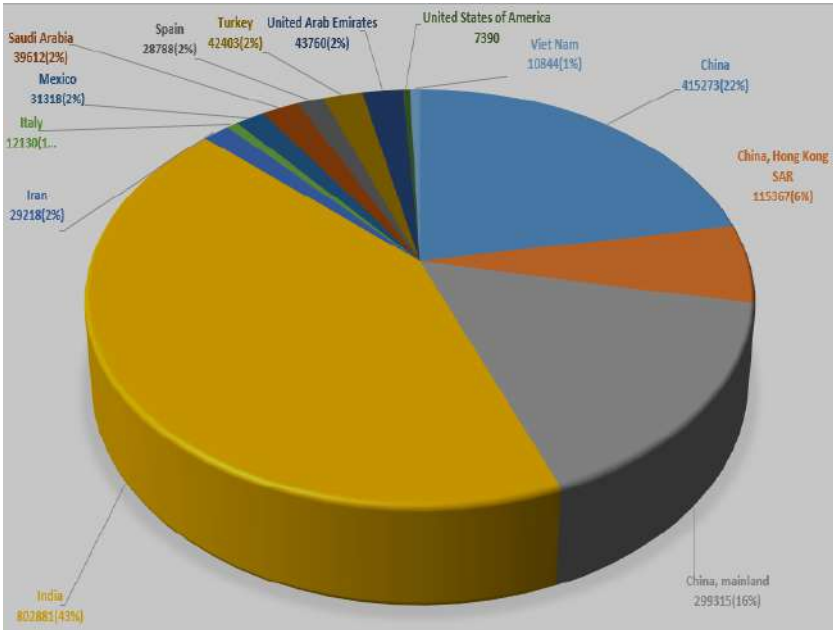


Fig.15. Top with shell almonds (1000 US$) importers by country in the year 2019

1.7. Production trend and harvested area harvested of almonds in Iran

According to the official reports of the Statistic and Information Center of the Agricultural Ministry of Iran in the year 2018, the total cultivation area of almonds in the country has been near 183 thousand hectares, of which nearly 150 thousand hectares are bearing trees. The report shows that 104 thousand hectares of the total are irrigated. Except in Mazandaran province, almond orchards are found in the other provinces of the country. Fars, Chaharmahal and Bakhtiari, East Azarbaijan, Kerman, Khorasan Razavi, Isfahan, Markazi and Hamedan provinces were the top eight almond producing provinces in the year 2018 (Anonymous, 2019) (Table 12).

A ten-year trend of the area harvested and production of almonds in Iran from 2009 to 2018 is shown in Figure 16. Almond fluctuations in almond production in Iran due to the late spring frost and early flowering of most almond cultivars cultivated in the country's orchards. If we consider the position and share of fruits in terms of area under cultivation, almonds are in the third place after grapes and apples (Figure 17).

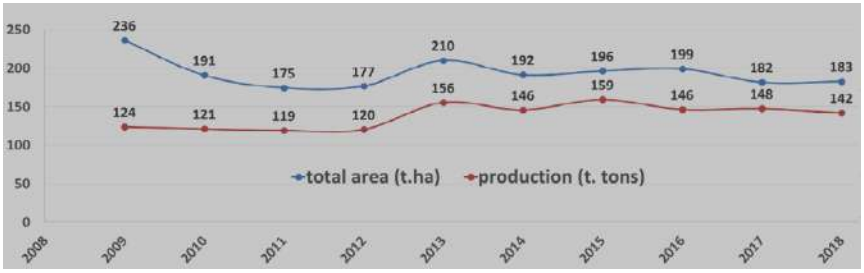


Figure16.The ten-year trend of production and area harvested of almonds in Iran from 2009 to 2018

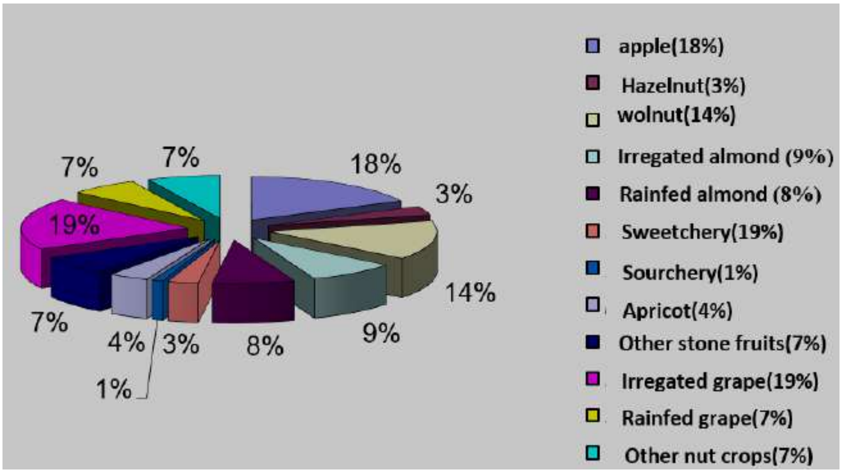


Figure 17. The situation of the Iran's cultivated areas in terms of position and share different fruits

Also, the situation of area harvested, production, and yield of almonds in Iran in the year 2018 is presented in Table 12. Among the provinces of the country, Khorasan Razavi, Fars, and East Azerbaijan, respectively, have the highest cultivated area, and Chaharmahal and Bakhtiari, Azerbaijan Sharghi, Fars, Khorasan Razavi and North, Markazi, and Kerman, respectively, have the largest share in almond production (Anonymous, 2019).

Table 12. Almond production and yield in the different provinces in the year 2018, Non-fertile (hectare) province, fertile (hectare) level, production (ton), yield (ton)

Province	Non-fertile level (hectare)			Fertile level (hectare)			Total level (hectare)	production (ton),			yield (ton)	
	Irrigated	Rainfed	Total	Irrigated	Rainfed	Total		Irrigated	Rainfed	Total	Irrigated	Rainfed
East Azerbaijan	1,939	724	2,663	8,137	1,124	9,261	11,924	10,530	576	11,106	1,294	512
West Azerbaijan	173	39	212	1,684	160	1,844	2056	3،160	138	3،298	1،876	863
Ardabil	56	46	102	144	82	228	330	124	16	140	864	188
Isfahan	602	1،399	2،001	6،487	1،359	7،846	9,847	7،773	223	7،995	1،198	164
Alborz	11	7	18	466	0	466	484	972	0	972	2,085	-
Ilam	38	48	86	56	57	113	199	88	52	140	1,560	912
Bushehr	0.5	0	0.5	7	0	7	7.5	8.4	0	8.4	1,200	-
Tehran	62	3	65	177	0	177	242	129	0	19	727	-
South Kerman	19	0	19	193	0	193	212	174	0	174	900	0
Chaharmahal and Bakhtiari	3,724	849	4,573	12,075	701	12,776	17,349	23,337	294	23,631	1,933	419
Khorasan-South	198	283	481	2,452	6,563	9,015	9496	3,712	2,598	6,310	1,514	396
Khorasan-Razavi	727	1,049	1,776	8,206	22,634	30,840	32,616	7,540	3,491	11,031	919	154
Khorasan-North	255	266	521	785	4,030	4,815	5336	1,060	2,525	3,585	1,350	627
Khuzestan	12	66	78	85	19	104	182	188	17	205	2,212	895
Zanjan	433	97	530	1,472	443	1,915	2445	487	41	328	195	92
Semnan	713	0	1,964	1,687	0	1,687	3,651	1,964	0	1,964	1,164	-
Sistan and Baluchestan	23	0	23	48	0	48	71	87.4	0	87	1,808	-
Fars	2,240	8,290	10,530	6,848	14,570	21,418	31,948	9,757	12,684	22,441	1,425	871

Province	Non-fertile level (hectare)			Fertile level (hectare)			Total level (hectare)	production (ton),			yield (ton)	
	Irrigated	Rainfed	Total	Irrigated	Rainfed	Total		Irrigated	Rainfed	Total	Irrigated	Rainfed
Qazvin	100	86	186	3,663	215	3,878	4064	1,465	53	1,518	247	400
Qom	25	0	25	600	0	600	625	162	0	162	270	-
Kurdistan	14	573	697	688	1416	2104	2801	882	879	1761	1282	621
Kermanshah	494	582	1076	1705	1669	3374	4,450	3708	2004	5712	2174	1201
Kerman	992	78	1070	10828	3100	13928	14998	9858	572	10430	910	185
Kohgiluyeh and Boyer-Ahmad	493	1275	708	295	414	923	1,631	598	325	1230	1020	210
Golestan	-	-	0	0	0	0	0	0	0	15	15	0
Gilan	1400	-	140	140	0	1	141	1	0	21	21	0
Lorestan	367	1365	4680	180	4500	3786	8466	490	3296	3,1583	68	1515
Markazi	424	57	430	6894	304	7198	7,628	9184	176	9360	1,232	579
Hormozgan	97	0	97	15	0	15	112	18	0	18	1,200	-
Hamedan	290	800	1090	3,259	2918	6177	7,267	6788	2216	9004	2083	760
Yazd	752	0	752	5656	0	5656	6408	4371	0	4371	773	0
Total	16092	16400	32491	87873	62454	150327	182,818	113124	29030	142154	1287	465

1-8 Perspectives of Iran's agricultural policy program in development with almonds

Iran with a production of more than 12.3 million tons is one of the major horticultural crop producers in the world. With the exception of some tropical crops, Iran has first to tenth place in the world in the production of many horticultural crops (Anonymous, 2019). On the other hand, more than a quarter of the country's working population is employed in agriculture. Considering the people working in different sectors of agriculture, it is not unreasonable to try to produce more, higher yields and desirable quality of these agricultural crops, because they can have a large share in the currency appreciation of our country through the export of agricultural products. Among the agricultural products, almonds can be considered one of the most important nut crops. However, the limitation of water and soil resources and the increase of population in our country have led researchers and policymakers to produce agricultural products following appropriate solutions to increase production and performance, and improve product quality. Among the 15 major horticultural crops, almonds are a horticultural crop that has economic, health, and commercial value and is important in terms of drought resistance due to Iran's location in arid and semi-arid regions and water scarcity in Iran, as well as ease of harvesting and transportation, preservation of fruits and job creation of almonds, has long been of special interest to Iranian farmers. Such goals are foreseen in Iran's agricultural policy program for the production of the desired agricultural crops. For example, this program emphasizes support for export-oriented agricultural crops, supporting breeding programs and production technologies, and increasing performance per unit area and productivity in crops with high export value. Almonds have all the advantages mentioned above. It has been shown that among nut crops such as almonds, walnuts, and hazelnuts, the apparent comparative advantage was for almond, walnut, and hazelnut equivalent to 5.2425, 1.595, and 0303, respectively. almonds after pistachio have the most obvious comparative advantage compared to other nut crops, and after that, walnut has the most obvious comparative advantage in Iran, which shows the advantage of exporting this product (Figure 18).

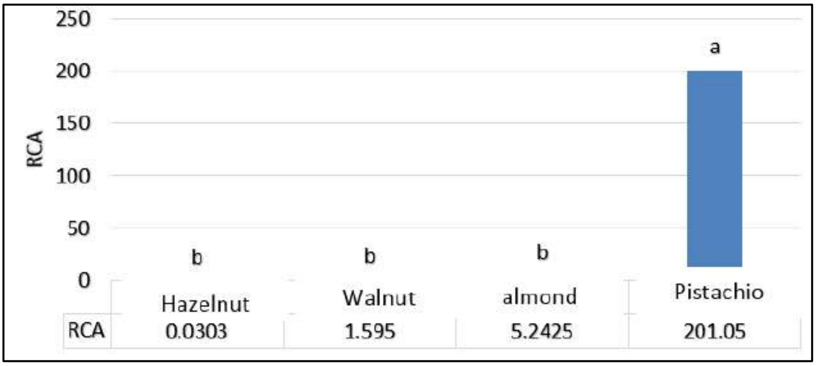


Figure 18. Relative advantage index of four nut crops of almond, walnut, hazelnut and pistachio

2- Challenges of the almond industry in Iran

Despite the relatively good advantages of almond production in Iran, there are some problems in the almond industry that should be overcome. The main challenges can be expressed in the low yield and quality of this nut crop. Of course, this challenge has many components, but the three items described below are great priorities.

2-1 Early flowering almonds and late spring frost

The main limiting factor in the development of the almond industry in Iran in the late spring frost. Almonds are one of the first flowering trees to bloom in the spring because of the low chill required in winter and the rapid reaction to the high temperature for spring growth. The early flowering habit of almonds limits their cultivation for many areas and their production in many years (Kester and Gradziel, 1996). Although research in recent years has helped mitigate this problem, spring frost sometimes causes the loss of more than 60 % of the crop and in some cases the entire crop in some important almond production areas in Iran (Chaichi, 2016).

(2-2 Lack of uniformity of almond rootstocks and cultivars

The almond trees in Iran were non-grafted until 1950. Since then, grafted almond orchards have been built in the country and their frequency has gradually increased. But even today, although many newly built orchards are grafted with the improved cultivars, the rootstocks used are mostly seedlings. The use of seeding rootstocks has led to a lack of uniformity in tree growth and resistance to adverse environmental conditions, pests and diseases. Non-uniformity is a negative factor in the export of almonds and competition with other almond-producing countries (Imani, 2005).

2-3 Low yield

The type of cultivars and rootstocks used in orchard establishment are among the factors influencing the yield. Regardless of the inherent capabilities and differences between cultivars and rootstocks in the amount of the yield, the adaptability to different environmental conditions including soil, climatic conditions and biotic and abiotic stresses, are factors affecting the quantitative and qualitative values of the orchards. Other factors such as water scarcity, poor nutrition and orchard management are also very important in this regard **(**Kester and Asay, 1975; Kester and Gradiziell 1996; Socias i Company, and Gradziel, 2017).

Self-incompatibility in almond is a genetic phenomenon and is gametophytic. In this type of incompatibility, the growth of the pollen tube in the middle of the style stops. The reason for this discontinuation is the presence of glycoprotein ribonucleases, called S-RNases. This trait in almonds is controlled by a multi-gene site (S-locus). The presence of similar alleles in pollen grains and pistil causes the pollen tube not to reach the ovary and stops during the style. A large number of S alleles under the names S_1, S_2, S_3...,and S_n are known in almonds and the dominant S_f allele has been introduced as a source of self-compatibility in almonds. Self-compatibility cultivars such as Tuono, Filiopo Ceo, Genco, Supernova and so on are known. The results of these researches are such that, today`s genotypes and high-quality and self-compatible cultivars have replaced the self-incompatible cultivars in almond orchards. Due to the non-grafted nature of the old orchards, there was no problem of pollen incompatibility in them, but this issue should be considered in the new orchards.

The subject of self-compatible is one of the most important issues in the world. Achieving to the self-compatible genotypes has been successful by using different methods of interspecies hybridization, intraspecific hybridization and induced mutations (Socias i Company, 1990).

The kernel is the edible part of almonds that results in the fertilization of an egg. Therefore, in order to produce almonds economically, it is necessary to have a suitable pollen grain in the orchard for pollination and fertilization (Mike, 1996). Most commercially grown almond cultivars are incompatible, and pollenizer cultivars are grown next to them. Cultivation of other compatible cultivars, even in orchards where self-compatible cultivars have been used, has led to increased yields of almond trees (Custer *et al*., 1994). Almond pollination is carried out by insects, especially honey bees. Due to the special conditions during almond flowering, such as low temperature, cloudy weather, wind and the presence of rainfall, beekeeping activity is limited, so it is necessary to provide conditions that ensure maximum pollen transfer between cultivars. For these reasons, it has been suggested that for commercial production in almond orchards, cultivars in a ratio of two to one and even one to one pollenizer cultivar and the main cultivar be cultivated (Custer *et al.*, 1994). According to the reasons mentioned above, the need to achieve self-compatible cultivars becomes clear and undeniable.

3- Almond research programs

3-1 Almond research programs in the World

Almond breeding began when humans chose domestic almonds and sweet nuts from the natural population of related species. orchard almonds were first domesticated in Asia, then moved to the Mediterranean and then to California. The distribution of almonds has undoubtedly been through seeds. Because the seeds can be stored for a long time and can be transported long distances. Almond cultivation by seed over the centuries has led to the creation of a range of superior genotypes and their selection by growers in almond-producing countries (Kester *et al*., 1994; Kester and Gradziel 1996).

Almonds have been propagated by seed only for 200 years in various parts of the Mediterranean Sea, and for more than a century, almonds have consistently endured the pressures of natural, climatic and artificial selection (by humans). The pressure of natural selection on species is very diverse and has given rise to the geographical populations of almonds. Therefore, the population of Sphax almonds in Tunisia has adapted to the environment in such a way that genotypes with chill requirements have been naturally removed from them. Or, on the contrary, the almond population on the Adriatic coast, which has the cold winds of the Alps, is made up of genotypes that have become accustomed to the conditions of the region with more chill requirements to become late bloomers. These physiological and ecological features along with some morphological attributes have led to the identification of different almond ecotypes in different regions (Kester *et al*., 1996).

Almond breeding began in the former Soviet Union in 1930 in Yalta, Crimea, and resulted in almond cultivars that could withstand Russian cold conditions, including Nikitsky, Yaltinsky, and Primorsky cultivars (Socias i Company and Gradziel, 2017). Almond cultivars were selected from the seeding population in France, and cultivars such as Ai, Princesse, Ardechoise, and Sultana were selected from the seeding population (Socias i Company and Gradziel, 2017).

The selected commercial cultivars in France were moved to California between 1850 and 1900, but these cultivars did not show good adaptation in California, so growers began to select local cultivars that had good adaptability and higher yields, and Nonpareil, IXL, Ne Plus Ultra, Texas (Mission), Drake, Peerless cultivars were selected and introduced by plant nursery (Kester and Asay, 1975) .Almond breeding in California began in 1923 and continues to do so, mainly by studying pollination and evaluating cultivars. The results of this program were breeding and introducing several cultivars and almond rootstocks (Kester and Gradziel, 2006).

In the field of selection of almond cultivars, France is one of the earliest countries. The almond breeding program in France began with the collection of germplasm from the Mediterranean countries and different countries such as Iran, Afghanistan and the former Soviet Union from 1951 to 1961, during which 450 genotypes from 10 different countries were collected and evaluated, and this collection formed the basis of the French almond germplasm. Controlled crossings began in 1961, resulting in the introduction of some new cultivars and rootstocks (Kester and Gradziel, 2006; Socias i

Company and Gradziel, 2017). Breeding programs have been initiated in various countries including the former Soviet Union (now Ukraine), Italy, Spain, and Australia to achieve new cultivars among the seeding population as well as controlled hybridizing, and they are still ongoing. Many of these cultivars have been introduced from these types of breeding programs (Kester and Gradziel, 2006; Socias i Company and Gradziel, 2017).

3.2. Almond research program in Iran

3.2.1. Cultivar breeding

In almond cultivar breeding, many traits are considered in the countries of the world, but in Iran, some traits as mentioned below, have important priorities and focusing on them might be useful to clarify the goal of the breeders to some extent.

3.2.1.1. Late flowering

One of the major challenges in growing almonds is frost, especially late spring frosts (Figure 19). Therefore, it is important to choose frost resistant cultivars. One of the best ways to prevent spring frosts is to choose late-flowering cultivars that can escape damage from late spring frosts (Figure 20).

Figure 19. Frost damage in almonds

Figure 20. The late flowering cultivar of almond in the almond collection in Karaj.

3.2.1.2. Bearing habit

The initiation of flower buds in almonds is lateral and on the spur and strong branches of the current year (one year) or the mixture (spur and one year) (Figure 21). Therefore, to increase the yield of almond cultivars with more flower production (spur type), it has more fruiting potential, but in this type of cultivar, the fruiting life of spurs is approximately 5 years. Therefore, it is necessary to prune them every 3 to 5 years to rejuvenate them.

Figure 21. Different bearing habits almonds: left; One-year-old branch; Middle, Mixed (spur and one-year); right, Spur

3.2.1.3. Pollination requirements

As mentioned earlier, Because the almond species is genetically incompatible, it acts as a barrier against the fruit set. On the other hand, the edible part of the almond is the kernel (seed), which needs to be pollinated and fertilized flower eggs. Therefore, in the breeding programs, almond bearing requires a suitable pollination composition of cultivars or using self- compatible cultivars. In order to maximize fruit, set, a compatible pollination composition in terms of suitable pollinizers and pollen recipients should be considered in the breeding program. However, achieving self-compatible almonds in almond cultivation development has entered the breeding programs of most countries in the world (Figure 22).

Figure 22. Increased yield with optimal pollination management

3.2.2. Rootstock breeding

Today, almond orchards use different rootstocks for optimal production. These rootstocks may be self- species (Figure 23) or intra- and inter-species hybrids (Figure 24). Their desirable characteristics include easy rooting, adaptability and tolerance to biotic and abiotic stresses. (Kester and Asay, 1975; Kester and Gradiziell 1996; Socias i Company, and Gradziel, 2017).

Figure 23. Almond species in natural conditions

Figure 24. Almond ×Peach hybrid

3.3. The stages of almond breeding and their achievements

The first local almond varieties were introduced by leading growers. Among them, varieties selected in Shahrekord such as Mamaee, Rabie and Sefid, those from Isfahan like Tajiri and Douw Bahre, Sanki and Dastmali from Khorasan and Falaq almonds in Maragheh (Azerbaijan) can be mentioned (Figure 25).

3.3.1. First Period

In Iran, research on fruit trees was started in 1928 by the General Directorate of Horticultural Studies. Initially, local cultivars of different fruits were collected and planted in the Karaj Collection orchard and after their preliminary evaluations, suitable cultivars were selected and introduced. With the establishment of the Seed and Plant Improvement Institute in 1939, these studies continued in major fruit growing areas of the country. The research has then been followed by the horticultural research department of the Seed and Plant Improvement Institute. Chaichi (from 1952 to 1992) has done a lot of research in the field of evaluation and preliminary studies and introduction of desirable varieties of almonds at that time. He has put in a lot of effort here, and it is only right to thank him for it.

At this stage, almond research actually began with the collection and evaluation of native germplasm and foreign cultivars in Iran. In this period (1945 to 1950) in addition to identifying, collecting and evaluating them at the same time as the imported cultivars of countries, in Horticultural Research Stations Karaj, Sahand Tabriz, Shahrood, Zarghan Fars and Torogh Mashhad began. After studying 120 native genotypes and 23 commercial varieties imported from the famous almond countries, one native cultivar called Sahand, 3 foreign cultivars (Ferragnès, Nonpareil and Ne Plus Ultra) in the Sahand Horticultural Research Station and some cultivars from other countries under the titles of Shahrood 21, Shahrood 17, Shahrood 18, Shahrood 15 and Shahrood 12 were selected at Horticultural Research Stations Shahroud, Shahroud, Semnan.

These cultivars were often late flowering and of good quality.

During the evaluation of foreign cultivars and native genotypes, a hybridization program for obtaining late-blooming cultivars at Sahand Horticultural Research Station was started by Saeed Chaichi (1965). Finally, 3 hybrid cultivars were obtained under the titles of Azar, Shokoofeh and Harir from this program (Figure 25).

3.3.2. The second period

At this stage, almond hybridization started in 1992. More than a thousand hybrids have been obtained by Ali Imani at Sahand Horticultural Research Station by crossing between selected late-flowering commercial cultivars selected in the first stage during 1992 and 1993. After an initial evaluation of 20 promising hybrids for selection, they are currently being studied at Karaj, Sahand, Shahrekord and Shahroud Horticultural Research Stations for final introduction, two of which are under the names of Eskandar and Araz were released (Figure 25).

3.3.3. The third period

At this stage, complementary indigenous almond germplasm selection and hybridization to achieve late-blooming cultivars with high quantitative and qualitative properties, especially cold stress-resistant (Socias i Company, 1990) by Imani 2000 has been using native cultivars as a parent since 2001 at the Karaj Horticultural Research Station. So far, thousands of genotypes and hybrids have been studied in this program. Most recently, two of them, named Saba and Aydin have been introduced. Also, along with the start of the third phase, three Italian self-compatible cultivars along with some commercial cultivars were evaluated in several regions of the country, including Karaj, Sahand, Shahrekord and Shahroud horticultural research stations. Finally, compatible Tuono and Supernova cultivars along with Ferragnès (Shared 12), were identified and recommended as adaptable cultivars for these areas. Today, these cultivars along with some selected cultivars in the first and second stages are propagated as superior cultivars and are used to develop almond orchards (Figure 25).

However, the cultivars that are more or less cultivated in different areas are listed below:

A230

It is a self-incompatible cultivar with semi-spread growth and large tree size, very late flowering, productive and fruiting habit of spur type and medium-sized fruit with a low double kernel, and a hard shell. A230 is recommended for cultivation in areas with frost risk. It has a very low to medium alternative bearing, which can be reduced by horticultural management. Pollenizers: A 200, Sahand, Ferragnès and Aydin.

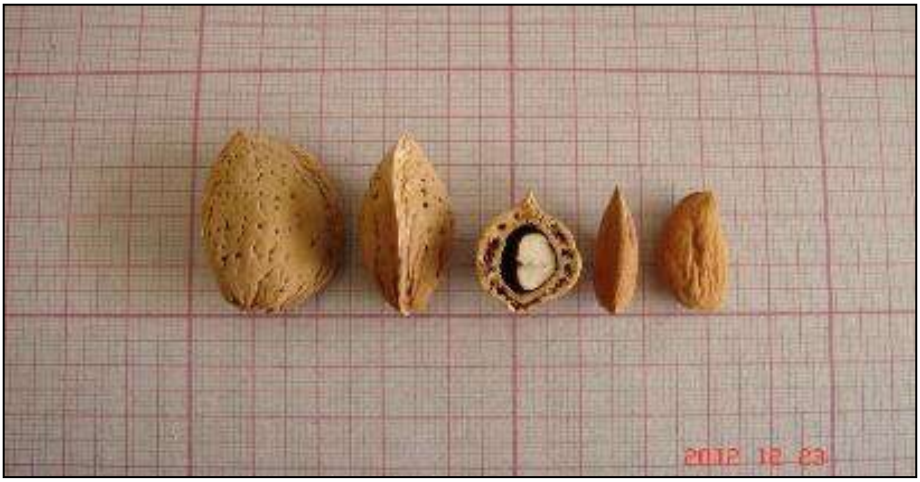


Figure 25-a. A230

A200

It is a self-incompatible cultivar with semi-spread growth and large tree size, very late flowering, productive and fruiting habit of spur type and medium-sized fruit with a low double kernel, and a hard shell. The A200 It is recommended for cultivation in areas with frost risk. It has a very low to medium alternative bearing, which can be reduced by horticultural management. Pollenizers: A 230, Sahand, Ferragnès and Aydin

Figure 25-b. A200

Shahroud 17

It is a self-incompatible cultivar with a spreading and small growth habit with hanging branches and medium tree size, late-flowering to very late flowering, a prolific and fruiting habit of spur type and medium fruit with low twigs and hard shell It is recommended for cultivation in areas with frost risk. It has a very low to medium alternative bearing, which can be reduced by horticultural management. Pollinizers: Nonpareil, Saba and Araz.

Figure 25-c. Sh-17

Nonpareil

It is a self-incompatible cultivar with a spread growth, large to very large tree, medium flower to late flowering, fruitful and habitual fruiting habit mixed and medium fruit with low double kernel and soft shell (paper shell). It is recommended for cultivation in areas with low frost risk. It has a very low to medium alternative bearing that can be reduced with horticultural management. Pollinizers cultivars: Araz, Saba, Azar and Ne Plus Ultra

Figure 25-d. Nonpareil

Eskandar

It is a self-incompatible cultivar with semi-spread growth, large tree, late flowering, productive and mixed fruiting habit, early ripening and medium fruit with low double kernel and soft shell (paper shell). It is recommended for cultivation in areas with low frost risk. It has a very low to medium alternative bearing that can be reduced with horticultural management. Pollinizers: Araz, Saba and Azar.

Figure 25-e. Eskandar

Araz

It is a self-incompatible cultivar with a spread growth, large tree, late flowering, productive and mixed fruiting habit, early ripening and medium fruit with low double kernel and soft shell (paper shell). It is recommended for cultivation in areas with low frost risk. It has a medium alternative bearing that can be reduced with horticultural management. Pollinizers: Eskandar, Saba and Azar.

Figure 25-f. Araz

Shahroud 7

It is a self-incompatible cultivar with a semi-spread growth and large tree size, very late flowering, productive and fruiting habit of spur type and medium to large fruit with the medium double kernel, and hard shell. It is recommended for cultivation in areas with high frost risk. It has a medium alternative bearing, which can be reduced by horticultural management. Pollinizers: A 200, Sahand, Ferragnès and Aydin.

Figure 25-g. Shi-7

Shahroud 12

It is a self-incompatible cultivar with a columnar growth and large tree size, very late flowering, productive and fruiting habit of spur type and large fruit without double kernel, and hard shell. It is recommended for cultivation in areas with high frost risk. It has a low alternative bearing, which can be reduced by horticultural management. Pollinizers: A 200, Sahand, Shahrood 7 and 13 and Aydin.

Figure 25-h. Sh-12

Shahroud 8

It is a self-incompatible cultivar with spread growth and large tree size, late flowering, productive and fruiting habit of spur type and large fruit with low double kernel, and hard shell. It is recommended for cultivation in areas with frost risk. It has a low alternative bearing, which can be reduced by horticultural management. Pollinizers: A 200, Sahand, Shahrood 7, Shahrood 13, Ferragnès and Aydin.

Figure 25-l. Shi-8

Tuono

It is a self-compatible cultivar with semi spread growth and large tree size, late flowering, productive and fruiting habit of spur type and large fruit with medium double kernel, and hard shell. It is recommended for cultivation in areas with frost risk. It has a low alternative bearing, which can be reduced by horticultural management.

Figure 25-i. Tuono

Shahroud 21

It is a self-incompatible cultivar with semi-spread growth and medium to large tree size, medium to late flowering, productive and fruiting habit of spur type and medium to large fruit with medium double kernel, and semi-hard shell. It is recommended for cultivation in areas with low frost risk. It has a high alternative bearing, which can be reduced by horticultural management.

Pollenizers: Eskandar, Saba and Azar.

Figure 25-j. Sh-21

Sahand

It is a self-incompatible cultivar with semi- columnar growth and large tree size, very late flowering, productive and fruiting habit of spur type and medium to large fruit with high double kernel, and hard shell. It is recommended for cultivation in areas with high frost risk. It has a high alternative bearing, which can be reduced by horticultural management. Pollinizers: A 200, A230, Ferragnès and Aydin.

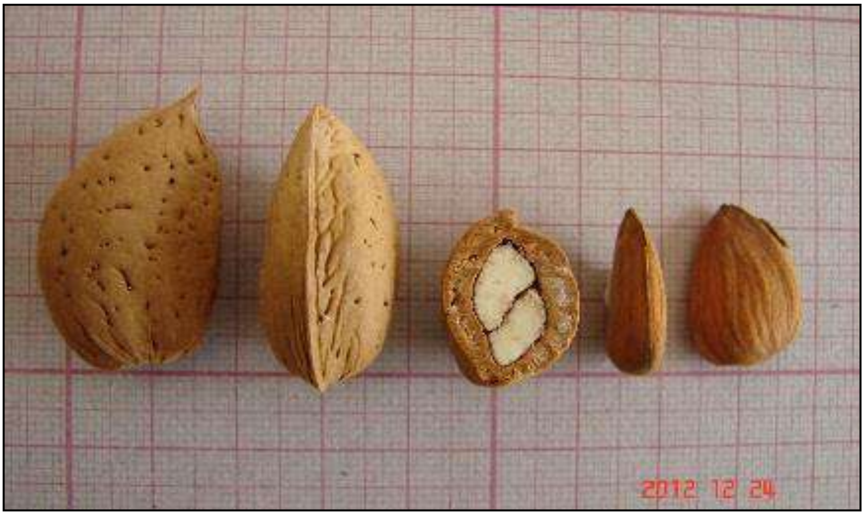


Figure 25-k. Sahand

Aydin

Self-incompatible cultivar with semi-spread growth and large tree size, very late flowering, productive and fruiting habit of spur type and medium to large fruit with medium double kernel, and hard shell. It is recommended for cultivation in areas with high frost risk. It has a ~~to~~ medium alternative bearing, which can be reduced by horticultural management. Pollinizers: A 200, Sahand, Ferragnès and shokoofeh

Figure 25-m. Aydin

Shokoofeh

Self-incompatible cultivar with spread growth, small tree, very late flowering, productive and mixed fruiting habit, early ripening and small fruit with very low double kernel and soft shell (paper shell). It is recommended for cultivation in areas with high frost risk. It has a high alternative bearing that can be reduced with horticultural management. Pollinizers cultivars: A 200, Sahand, Ferragnès and Aydin

Figure 25-n. Shokoofeh

Saba

Self-incompatible cultivar with spread growth and large tree size, late flowering, productive and fruiting habit of mixed type and large fruit with low double kernel, and soft shell. It is recommended for cultivation in areas with low frost risk. It has a medium alternative bearing, which can be reduced by horticultural management. Pollinizers: Eskandar, Araz and Azar

Figure 25-o. Saba

Azar

It is a self-incompatible cultivar with with-semi-spread growth and medium to large tree size, medium to late flowering, productive and fruiting habit of spur type and medium fruit with low double kernel, and semi-hard shell. It is recommended for cultivation in areas with low frost risk. It has a high alternative bearing, which can be reduced by horticultural management.

Pollinizers: Eskandar, Saba and Arar.

Figure 25-r Azar

Mamaee

It is a self-incompatible cultivar with spread growth and large tree size, early flowering, productive and fruiting habit on One-year-old branch type and large fruit with high double kernel, and hard shell. It is recommended for cultivation in areas with very low frost risk. It has a medium alternative bearing, which can be reduced by horticultural management. Pollinizers: Rabie, and Sefid.

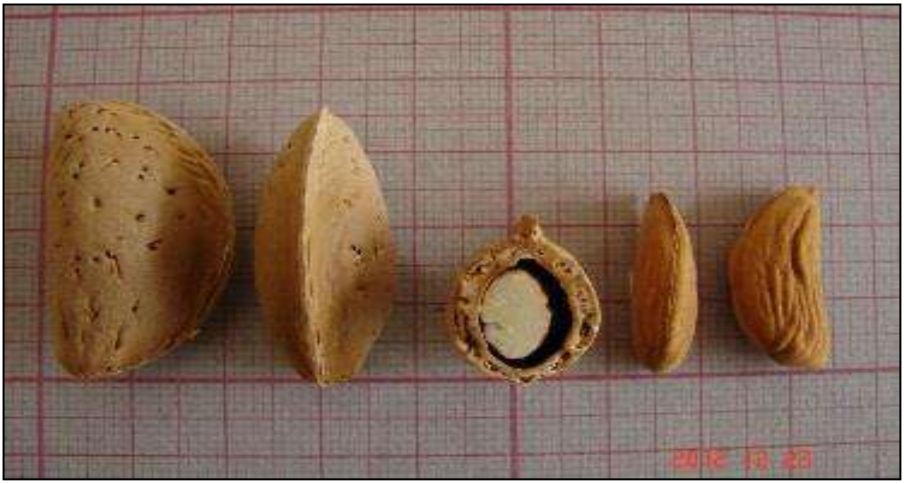


Figure 25-s. Mamaee

Rabie

It is a self-incompatible cultivar with columnar growth and large tree size, early flowering, productive and fruiting habit on spur type and large fruit with high double kernel, and hard shell. It is recommended for cultivation in areas with very low frost risk. It has a low alternative bearing, which can be reduced by horticultural management. Pollinizers: Mamaee and Sefid.

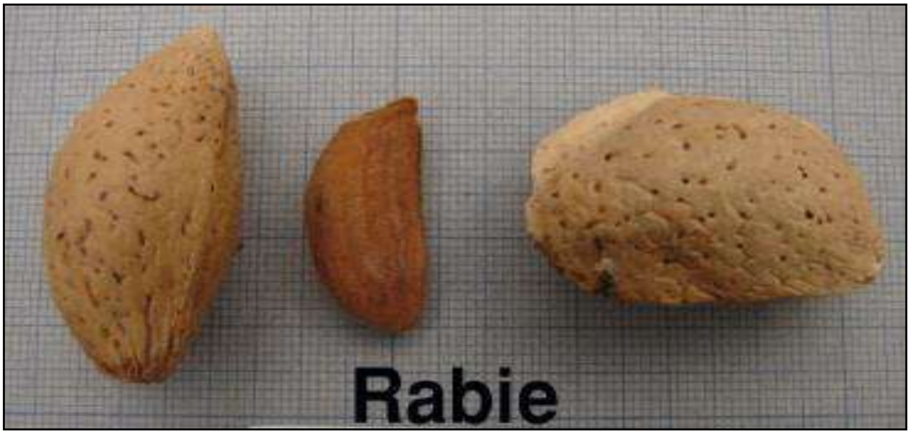


Figure 25-v. Rabie

Sefid

It is a self-incompatible cultivar with semi- columnar growth and medium tree size, very early flowering, productive and fruiting habit of mixed type and medium fruit with low double kernel, and semi-soft shell. It is recommended for cultivation in areas with very low frost risk. It has a high alternative bearing, which can be reduced by horticultural management.

Pollenizers: Rabie and Mamaee

Figure 25-w. Sefid

Shahroud 15

It is a self-incompatible cultivar with spread growth habit and large to very large tree size, late flowering, fruitful and mixed fruiting habit and very small fruit with low double kernel and soft shell (paper shell). It is recommended for cultivation in areas with frost risk. It has a very low to medium alternative bearing, which can be reduced by horticultural management. Pollinizers: Shahroud 17, Nonpareil and Tuono

Figure 25-z. Shahroud 15

3.2.4. The fourth period

At this stage, almond hybridization started in 2010. In this program, more than 8000 hybrids have been obtained by Ali Imani at Karaj Horticultural Research Station between 2010 and 2011 using a combination of 40 cross-selective cultivars of late-flowering cultivars and self-compatible cultivars. After the initial evaluation, 50 promising genotypes were selected for introduction, and now in the form of a contract with the private sector, with the help and coordination of the Horticultural Research Institute, they are conducting a study of their regional compatibility for the final introduction. It is hoped that the program will introduce several new cultivars of almonds (Figures 26, 27 and 28) so that in the future the country's almond industry will be based on them. Some of their features are shown in Figures 26, 27 and 28.

Figure 26. Fruit of some almond genotypes compared to Nonpareil (best in terms of fruit quality)

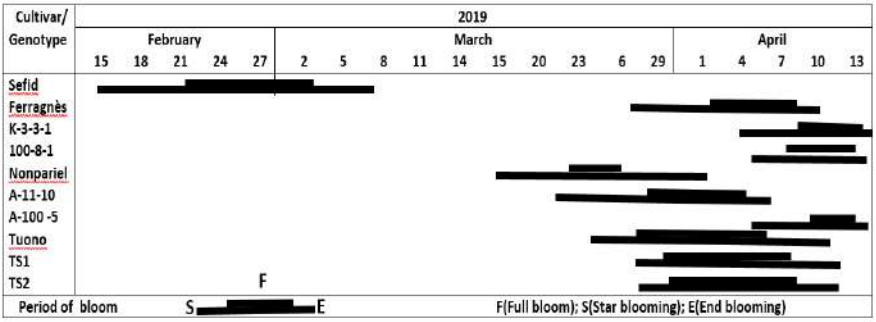


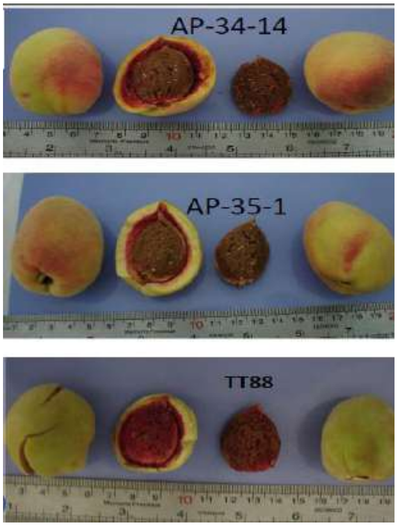
Figure 27. Flowering time of some almond genotypes compared to almond Nonpareil (a standard cultivar, especially in terms of fruit quality and area cultivated).

Figure 28. Genotype 1-16: Late flowering, fruitful and uniform and good quality soft fruit

In addition to the cultivar, the rootstocks breeding program is also being implemented by examining the compatibility of imported (foreign) rootstocks and using the selection method and hybridization in the form of a codified program in Karaj, Tabriz and Shahrekord. In this regard, two foreign rootstocks of GF677 and GN15 have been properly identified and are being used in development programs.

Also, from the rootstock breeding program in Karaj, a mutant rootstock from GN15 rootstock (with red leaves) called GN2 rootstock (unlike GN15 rootstock with green leaf blade with red veins and more desirable than GN15 compared to stresses such as drought) is being introduced. In addition, four hybrids (with TT4, P34-12, P34-8 and P50-4 codes) from crossing between bitter almonds No. 22 with chlorosis-resistant nectarine are selected among the 120 hybrids obtained in 2011 (Figure 29). Now these promisings, as well as other promising rootstocks in Tabriz, are in the stage of final evaluation for the introduction.

AP-34-14



AP-34-14: Strong growth, ease of propagation and can replace existing rootstocks.
AP-35-1: Strong growth, ease of propagation and resistance to chlorosis and can replace existing rootstocks
TT 88: Strong growth, ease of propagation and resistance to chlorosis can replace existing rootstocks.

Figure 29. Hybrids between peach, nectarine and almond species

4. Global strategies and experiences to solve major problems in almond production

Despite the relative advantage of almonds, there are problems with the production of almonds that must be over the barriers. In this regard, the use of world experiences can be used to solve problems, the most important of which are mentioned below:

4.1. The main problems of almond

Almond production has many problems, but the low quantity and quality of the product are the main problems of almonds. These problems have many components, but the following three are of great priority:

4.1.1. Almond spring frost damage

Spring frost is one of the major problems in growing almonds. For example, the compensation paid for frost damage in almonds during the last 7 years is equal to 24311995070 Rials, which is the highest compensation for Chaharmahal and Bakhtiari, East Azerbaijan, Khorasan Razavi provinces. As a result, the following simple calculation will determine the importance of the amount of damage caused by frost, which has the ability to reduce the produced almonds in Iran.

Spring frost damage (case)

Almond production in Iran is 154,000 tons, if spring frost damage is considered an average of 40%. It has the potential to produce 256000 tons. If we consider an average of 100000 tomans per kilo of almonds, the total income of almonds in a year is 6160 billion tomans and the damage caused by frost is equal to 102000000000 tomans (note the following relations):

154000 tons × 1000 = 154000000 kg × 100000 Tomans = 15400000000000 Tomans Total almond incomes in one year

Frost damage= 102000000000Tomans

Production potential without frost (total income of almonds in one year): 358000 tons × 1000 = 358000000 kg × 100,000 Tomans = 35800,000,000,000 Tomans

Approach

However, spring frost damage is a major challenge in almond production. Anyway, it is possible to prevent this problem by selecting late-flowering and improved cultivars. Therefore, late flowering cultivars and compatibility with the production area are two of the influential factors in the successful cultivation of almonds (recommended late flowering and frost-resistant cultivars).

4.1.2. Lack of proper pollination management in almonds

A) Global experiences and knowledge of almond pollination optimization using horticultural operations

B) Low yield occurs in almonds for a series of reasons (including the self-incompatibility of most almond cultivars and problems with optimal pollination). In almonds, the edible part is the kernel or seed, which is caused by the fertilization of flowers by insects, especially honey bees (90%) (Figure 30). If fertilizations do not occur, the kernel or seed production is zero. But unfortunately, in Iran, less attention is paid to this issue. For example, the average percentage of almond fruit set in Australia and Iran is 27-30% and 9.2-12. %, respectively. Today, it has been proven that increased production can be expected when pollination management is done properly (Figure 30).

A)

B)

C)

D)

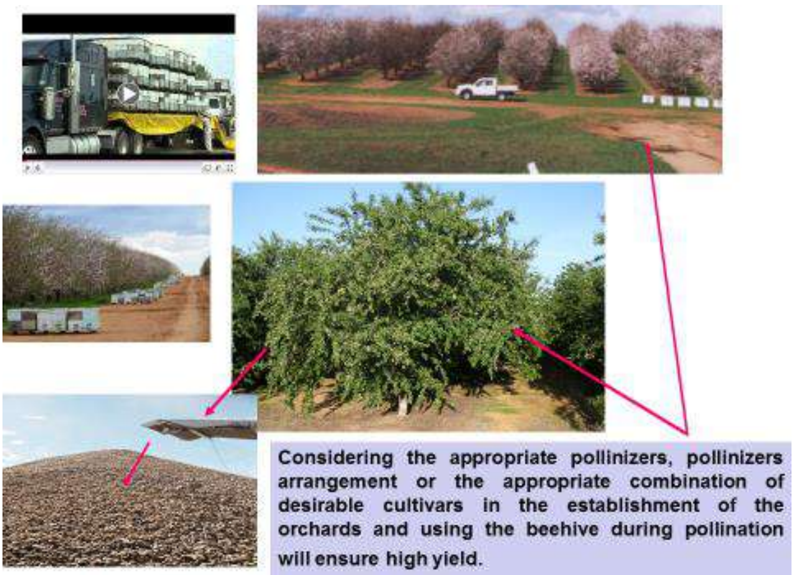
Figure 30. A, B)Pollination requirements and C, D) Pollination effect on fruit set and production (upper right branch with fruit set due to complete pollination and left branch incomplete pollination) (Imani and Zeinalabedini, 2019)

On the other hand, almond flowers are ready to be pollinated immediately after opening (Figure 30C). Studies have shown that flowers that bloom one day after opening have a 30% ability to set fruit, 21% ability 3 days after opening and only 1% ability 5 days after opening (Table 13) (Griggs and Iwakiri, 1964). Therefore, proper pollination management (considering proper pollenizers, pollination arrangement and use of beehives during pollination) can increase the production and economic efficiency along with other factors affecting fruit formation and production. Therefore, it can be seen that the highest percentage of increases in production may be related to pollination management (Figure 31).

Table 13. Percentage of fruit set in almonds due to fertilization at different times after flowering

5 days after fertilization of flowers	3 days after fertilization of flowers	1 days after fertilization of flowers
1% fruit set ability	21% fruit set ability	30% fruit set ability

(A)



(B)

Figure 31. Proper pollination management in Australia (A) and the United States (B) ensure that yield increases are several times higher than in other producing countries

The single most important factor determining a good yield is pollination during the bloom period.

• About 1.6 million colonies of honey bees are placed in California almond orchards at the beginning of the bloom period to pollinate the crop

• After almonds, honey bees move throughout the United States, pollinating over 90 other crops and making honey

• The Almond Board of California recently released a comprehensive set of Honey Bee Best Management Practices (BMPs) for California's almond industry

• The Almond Board of California has taken a leadership position in engaging and collaborating with universities, government agencies, nonprofits and beekeeping groups to communicate, educate and inform honey bee research, policy, education and outreach.

In the leading country, almond production, like in the United States, spends about 14.2 percent of the cost of managing almond orchards on managing pollination, including renting beehives. How much does it take in other countries including Iran? Please note the following figure.

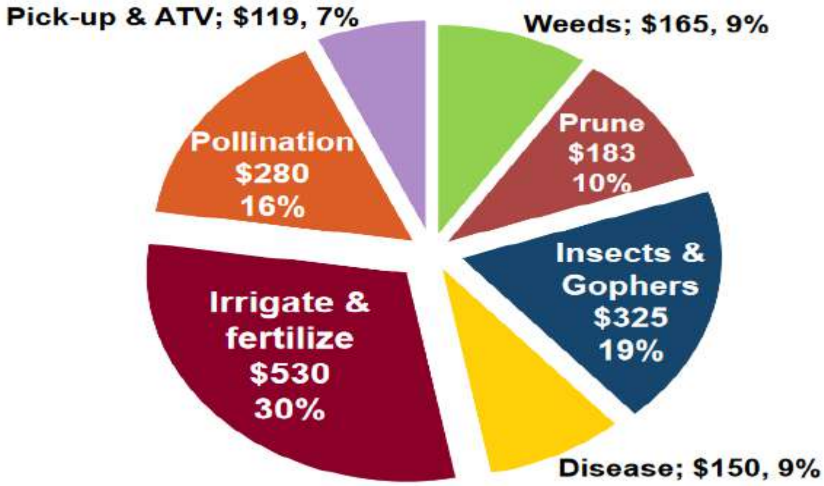


Figure 32. Almonds culture costs 1,752 US$ per acre

The cost of managing almond pollination uses suitable pollinizer cultivars and their optimal distribution in almond orchards. One of the factors in increasing the yield of almond orchards is the use of suitable pollinizers and their optimal distribution in almond orchards. The overlap of the flowering period, abundant flower production, long flowering period and pollen grains are characteristics of pollenizer cultivars. When establishing an orchard and planting tree, the location and arrangement of the pollenizers is more important than the original cultivar in the orchards. In this regard, different arrangements of pollenizers are used in relation to the main cultivar, examples of which are presented in Figures 33 to 37. This factor can be one of the most effective reasons for the high yield per unit area (5.26 tons per hectare) in the United States compared to the yield of almond orchards in other countries (Figure 7).

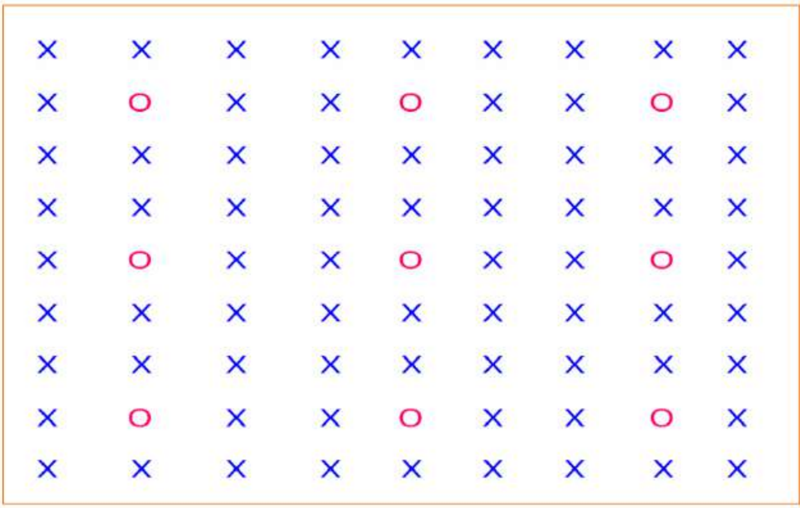


Figure 33. Cultivation method 1 to 8: X = Main cultivar; O = Pollenizer

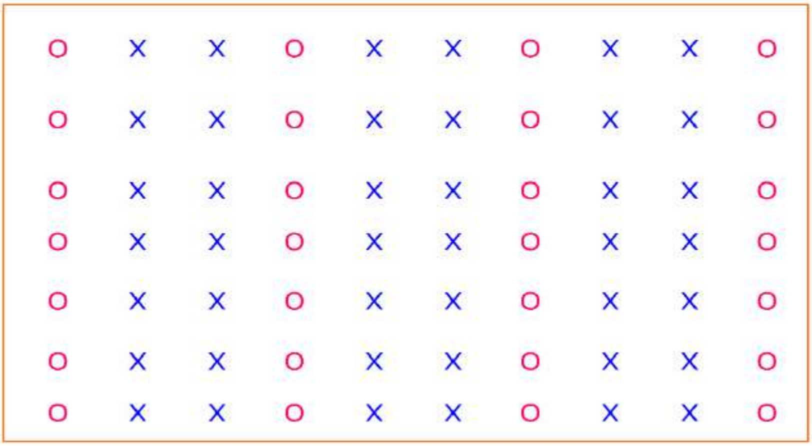


Figure 34. Cultivation method 1 to 3: X = Maincultivar; O = Pollenizer

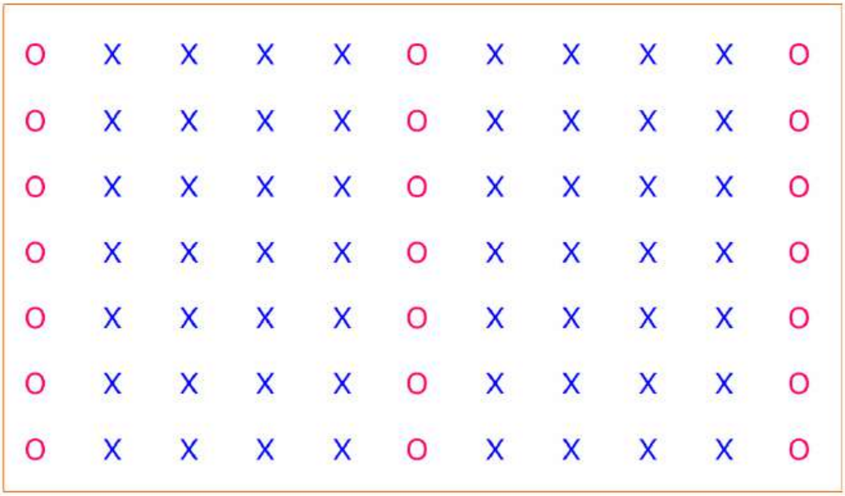


Figure 35. Cultivation method 1 to 5: X = Main cultivar; O = Pollenizer

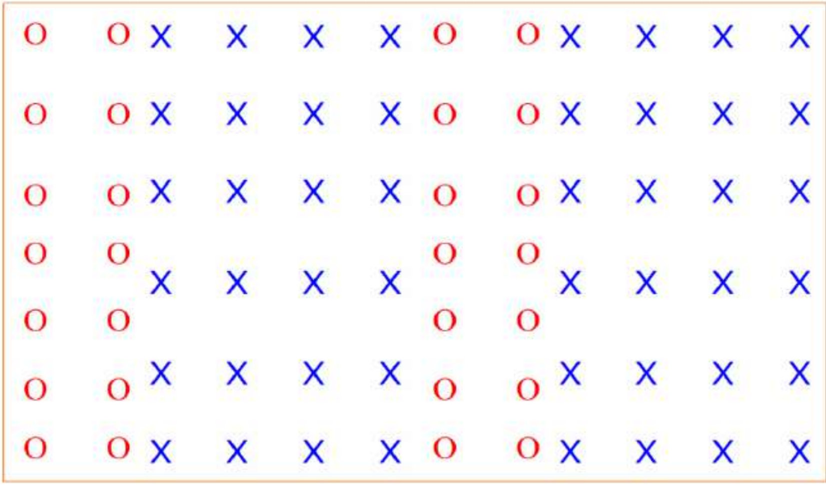


Figure 36. Cultivation method 2 to 6: X = Main cultivar; O = Pollenizer

Figure 37. Arrangement of suitable pollinizer cultivars with receiver pollen cultivars in terms of synchronization of the flowering period in almond orchards of California (one of the main reasons for the increase in yield and growth of the almond industry in California)

Pollination damage (case)

Fruit set in the process of pollination averages 27 to 30 percent in almonds, while the average is around 12 percent in Iran. Approximately, the yield of almonds in Iran is 1.2 tons. Therefore, the damage caused by not pollinating can be expressed as follows:
Almond production in Iran is 154,000 tons, while the production potential is 30.800.000.000.000 tons (almost doubling the fruit set). If we consider an average of 100,000 tomans per kilo of almonds. Note the following relations:

154000 tons × 1000 = 154000000 kg × 100.000 Tomans = 15400000000000 Tomans. Total almond incomes in one year

Damage caused by pollination= 15400000000000Tomans

Approach

Proper pollination management Considering the appropriate pollinizers, pollinizers arrangement, or the appropriate combination of desirable cultivars in the establishment of the orchards and using the beehive during pollination will ensure a high yield.

To do this, the first step is to create awareness in the target communities (experts in the field and exploiters) and to identify and explain the importance of the issue by holding training and practice workshops for almonds in the field of proper pollination management. Implementing pilot orchards in important provinces can pave the way for raising awareness about the need to take action to take the necessary steps to achieve proper pollination management and ultimately increase almond production.

4.1.2.1. Global experiences and knowledge of almond pollination optimization using breeding programming

To reduce the destructive effects of non-pollination damage on incompatible cultivars (in unfavorable pollination conditions), almond breeding programs to achieve self-compatible cultivars in the world's almond-growing countries, including Italy (through selections and mutations) Spain, and the United States (through hybridizing) (Socias i Company,1990). These programs have been really successful, and more than 20 different cultivars have been introduced (Table 14). California programs have often used peach and almond hybridizing to achieve their self-compatible cultivars, which have not been very successful. Anyway, European programs, especially in Spain and France, use self-compatible cultivars mainly Tuono selected in the Italian region of Puglia as their source of self-compatible. Today, many self-compatible cultivars have emerged that are cultivated on a large scale, which reflects the real need for self-compatible cultivars for the growth of the almond industry and has been very effective in growing and increasing production (Socias i Company, 1998).

Table 14. Self-compatible almond cultivars introduced from breeding programs (Eddy, 2011; Socias i Company et al.,2011)

Cultivar	Origin
Spain	
CITA de Aragón (Zaragoza)	
'Guara'	Clonal selection
'Aylés'	'Tuono' OP
'Blanquerna'	'Genco' × AS-1
'Cambra'	'Ferragnès' × 'Tuono'
'Felisia'	'Titan' × 'Tuono'
'Belona'	'Blanquerna' × 'Belle d'Aurons'
'Soleta'	'Blanquerna' × 'Belle d'Aurons'
'Mardía'	'Felisia' × 'Bertina'
'Vialfas'	'Felisia' × 'Bertina'
CEBAS-CSIC (Murcia)	
'Antoñeta'	'Ferragnès' × 'Tuono'
'Marta'	'Ferragnès' × 'Tuono'
'Penta'	S5133 × 'Lauranne'
'Tardona'	S5133 × R1000 ('Tardy Nonpareil' × 'Tuono')
IRTA – 'Mas de Bover' (Reus)	
'Francolí'	'Cristomorto' × 'Tuono'
'Constantí'	('Ferragnès' × 'Ferraduel') OP
'Marinada'	'Lauranne' × 'Glorieta'
'Vairo'	('Primorskij' × 'Cristomorto') × 'Lauranne'
France	
INRA (Avignon)	
'Lauranne'	'Ferragnès' × 'Tuono'
'Steliette'	'Ferragnès' × 'Tuono'
'Mandaline'	'Ferralise' × 'Tuono'
USA	
University of California (Davis)	
'Sweetheart'	SB3, 54-39E (('Lukens Honey' peach × 'Mission') × 'Nonpareil') × Sel 25-26
Zaiger Genetics	
'Garden Princess'	('Merced' × dwarf peach)
'All-in-One'	F_2 from peach
'Independence'	'All-in-One' × 21G8 almond seedling
Israel	
Agricultural Research Center (Newe-Ya'ar)	
'Matan'	'Lauranne' × 'Um El Fahem'

Today, new orchards have been established in the Mediterranean countries, including Spain, using self-compatible almond cultivars. The yield of these orchards is sometimes double that of traditional orchards, which shows a promising outlook. It has also started as a successful experience in Iran (Figures 38).

Figure 38. Examples of almond orchards established from new self-compatible almond cultivars in Spain

In summary, the world's experience in optimal almond pollination management shows that:

1. The average percentage of almond fruit set in Australia is 27-30% and in Iran, it is 9.2-12 %. Pollination management accounts for more than 60% of the increase in output.
2. About 1.6 million bee colonies are placed in California's almond orchards at the beginning of flowering to pollinate and combine the proper cultivation of almond cultivars in the garden. More than 60 percent of the world's almonds are produced in California (the world's first almond producer) at a lower cultivation level than in Spain (the second largest producer).
3. Use self-compatible almond cultivars mainly in Spain, Italy, France and other almond-producing countries of the world

(establishment of monoculture orchards or cultivation of a cultivar in almond orchards and guarantee of pollination in adverse pollination conditions).

Therefore, according to the explanation inside the box, the amount of damage caused by the lack of proper management of pollination in almonds in Iran has been well clarified.

4.1.3. The seedling orchards

The country's almond trees were non-grafted until 1950. Since 1950, grafted almond orchards have been built in the country and their percentage has gradually increased. Even today, although many of the newly established orchards have been grafted with good cultivars, the old orchards and used rootstocks are still mostly seedlings. Seeding orchards and the use of seed rootstocks have led to a lack of uniformity in tree growth and different levels of resistance to adverse environmental conditions, and pests and diseases. Non-uniformity is a negative factor in the export of almonds and competition with other almond-producing countries (Imani *et al*., 2000). As a result, the cultivars and rootstock used in the orchard's establishment are also important factors in yield increase.

Regardless of the inherent capabilities and differences between cultivars and rootstocks in the amount of yield, the compatibility of cultivars and rootstocks with environmental conditions including soil, climatic conditions and biotic and abiotic stresses is a factor affecting the quantity and quality of orchards. Although they are out of the scope of this report and are not addressed, water scarcity, poor nutrition and garden management are also very important in this regard (Figures 39). Although new orchards are established in accordance with technical principles (Figure 40), there is a need to increase the awareness of the beneficiaries by holding education and extension workshops and creating pilot orchards.

Figure 39. An example of almond orchards established in the area with poor management of trees in the orchards. Without applying to prune and managing the orchard floor and creating a catchment system, etc. (right), and plowing, and without other gardening operations such as pruning, creating a catchment system, etc. (left)]in the province of North Khorasan

Figure 40. View of a 4-year-old almond orchard in the Fars province

Damage caused by seedling orchards with low quality and quantity (case)

The presence of seeding orchards is one of the most significant challenges for almond cultivation in Iran. Therefore, in these types of orchards, most of the trees, each of which is a genotype, are early flowering and are often damaged by late spring frosts. Due to the non-uniformity of the crop, in the years that produce the crop, they do not produce a good quality and quantity of crop (Figure 41). In addition to orchard operations such as training and pruning, nutrition, crop harvesting (non-synchronization of crop ripening, sorting, packaging, etc.) and so on, the problem is encountered. Therefore, the establishment of orchards with improved cultivars can have a great economic effect in terms of productivity. For example, if we consider the total production of almonds in the country, which is 154000000 kg. If this production is considered under the current conditions, and at the price of 100.000 Tomans per kilogram (non-uniformity of the product), we can expect an income of 15.400.000.000.000 Tomans. If the same production is allocated for improved cultivars and taking into account the price of 150,000 Tomans per kilogram (uniformity and quality of the product), the income will be equal to 231,100,000,000,000 Tomans.The difference in income will be 7,700,000,000,000 Tomans.

Approach

As mentioned above, the experience of leading countries in the almond industry, such as the United States, Spain, Australia, etc., shows that the use of improved cultivars in the development of new orchards and the use these improved cultivars in the development of new orchards can prevent this huge damage. Because these cultivars, in addition to high yield, are cold tolerant and have a flowering time of at least 10 to 20 days compared to native cultivars. Therefore, the promotion and development of the cultivation of this improved cultivar can have good economic effects on the country.

Therefore, one of the most important ways to eliminate this shortcoming in the country's almond-growing industry, like in other leading countries, is to create awareness in target communities (experts in the field and operators) and identify and explain the importance of the issue by holding workshops. It is common for farmers to replace substandard almond trees with improved and late-flowering cultivars. Also, the implementation of pilot orchards in important provinces can make it possible to raise awareness and use it to replace substandard almond trees with improved cultivars and establish new orchards with improved cultivars, which will ultimately increase the production of the almond crop.

Figure 41. Seedling orchards with non-uniform crops

4.1.4. Other problems in almond orchards

However, these problems are not as much of a priority as the three major almond problems mentioned above. Briefly, this type of almond problem is referred to as below:

4.1.4.1. Lack of attention to irrigation management

Irrigation management is especially important in the critical stages of almond trees. For example, irrigation should never be stopped near the harvest stage depending on the type of cultivar. Because almond trees are sensitive to water stress in the post-harvest stage, and flower buds are formed for the next year at this stage, it is necessary to irrigate to prevent a decline in next year's yield. Lack of irrigation and low water stress in the previous year's post-harvest period have been reported in almond trees (Mousavi *et al*., 2009).

4.1.4.2. Inadequate soils with low fertility, an especially low percentage of organic matter in the soil

Most of the major challenges (stresses) of agricultural production are directly related to nutrition and fertilization and should be managed in this way. Growing almonds, like other temperate zone fruit trees, has many nutritional problems. Although this tree survives well in hard and rocky soils and is adapted to drought, it should be borne in mind that the high resistance of the almond tree is not the reason for the lack of irrigation and other necessary care of the orchard. The more complete the care of the tree and regular irrigations cause the higher the quantity and quality of the almond crop. Strong almond roots can tolerate activated lime (20 to 30%) in the soil, but almonds are more or less sensitive to soil and irrigation water salinity. Various studies have shown that almonds are among the fruit trees relatively sensitive to salinity. Almond trees can grow well in soils with low salinity and their yield is not reduced until the electrical conductivity of 1.5 dS/m, while in salinity, 2.8 dS/m by 25 % and 4.1 DS/m by 50% and finally at 7 dS/m by 100% of their yield is reduced. Also in irrigation, almond is able to withstand up to 1.1 g/l of chlorine and its reduction in yield to water salinity is similar to soil salinity. However, limiting factors for almond root growth include soil texture, soil depth, groundwater level and water-logging. Heavy soils are not suitable for almonds due to high moisture retention and insufficient drainage. Its cultivation in clayey and wet soils stops its growth and development. If almond cultivation is on wet clay soil, it should be grafted on rootstocks that are both resistant to soil moisture and graft compatible with almonds. Sandy soils, unlike heavy soils, lose moisture very quickly and are poor in nutrients. Therefore, soils with light, fertile, deep texture and good drainage have the best growth and development, and in these soils, almond roots can penetrate up to about 3 meters or more.

Determining the current nutritional status of almond trees can be done observationally by examining the presence of certain symptoms such as leaf discoloration, chlorosis, necrosis, small leaves, lack of growth and development and so on. But it should be remembered that the effect and differentiation of physiological, pathological and climatic factors with the symptoms of nutritional deficiencies and poisoning are not easily recognized. In addition, soil sample preparation, determination of soil physical and chemical conditions, and fertilizer management should be carried out. Almond cultivated soils in Iran mainly have a light and sandy texture and mainly need a lot of attention in terms of fertilizer application. Due to the lack of nutrients, the trees are often Low-growing and weak, which in addition to low load, has also led to susceptibility to diseases and pests (Imani, 2015).

4.1.4.3. The production of standard and certified plants

Due to a lack of attention to the originality and health of plants (rootstock and scion) and organizing, the production and management of standard and certified plants are the most influential factors. Because the cultivars and rootstocks used in the orchard's establishment are also factors influencing yield increase.

4.1.4.4. Reduce production costs

In the almond operation in Iran, before the construction of the orchard for preparing orchard land, leveling machines are used, and other stages of work are completely traditional. As a result, the most pressing issues for growers in the country are high production costs, a low mechanization coefficient, and a lack of garden hygiene in production (avoiding contact with water or moist soil on tree crowns and trunks, removing dry, pest, and diseased trees or branches and burning them, removing infected and rotten fruits and burning them, weeding, and disinfecting pruning equipment with bleach solutions). In this regard, attention to climatic location and determination of areas prone to almond cultivation, attention to suitable climatic and soil conditions in the construction of orchards, proper management of horticulture, management and control of pests and diseases, use of cultivars and rootstocks resistant to biotic and abiotic stress, use of cultivars having higher yield potential, early fruiting and higher yield stability, the use of suitable mechanical harvest cultivars that are easy to harvest and peel (green skin), play important roles in reducing costs. Therefore, reducing production costs, along with increasing yield per unit area with a correct view of the needs of the market and almond trade, will lead to the success of the almond industry. In all of these cases, in addition to genetic control, environmental and managerial factors are of particular importance and can lead to differences in breeding programs in different regions and countries according to climatic, managerial and marketing conditions (Mike, 1996; Kaster *et al*., Gradzil, 1996).

5. Global experience and knowledge about the development of modern orchards with technical principles

5.1. Almond's experience in the United States and Australia

The establishment of orchards with technical principles in countries such as the United States (Figures 42 and 43) and Australia (Figures 44 and 45) have caused the growth of their country's almond industry to multiply.

Figure 42. Example of an almond orchard established in California (Note: the lack of vegetation on the rows and the presence of vegetation between the rows).

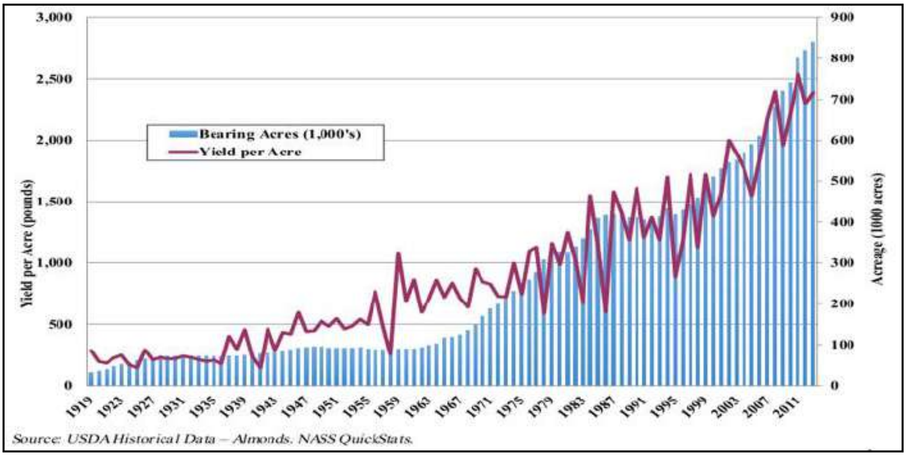


Figure 43. The growth of the almond industry is affected by the promotion of technical issues and compatible cultivars and suitable planting sites

Figure 44. Example of almond orchards established in Australia (Note: the management of the orchard floor. Lack of vegetation on the rows and the presence of vegetation between the rows, and the use of special machines)

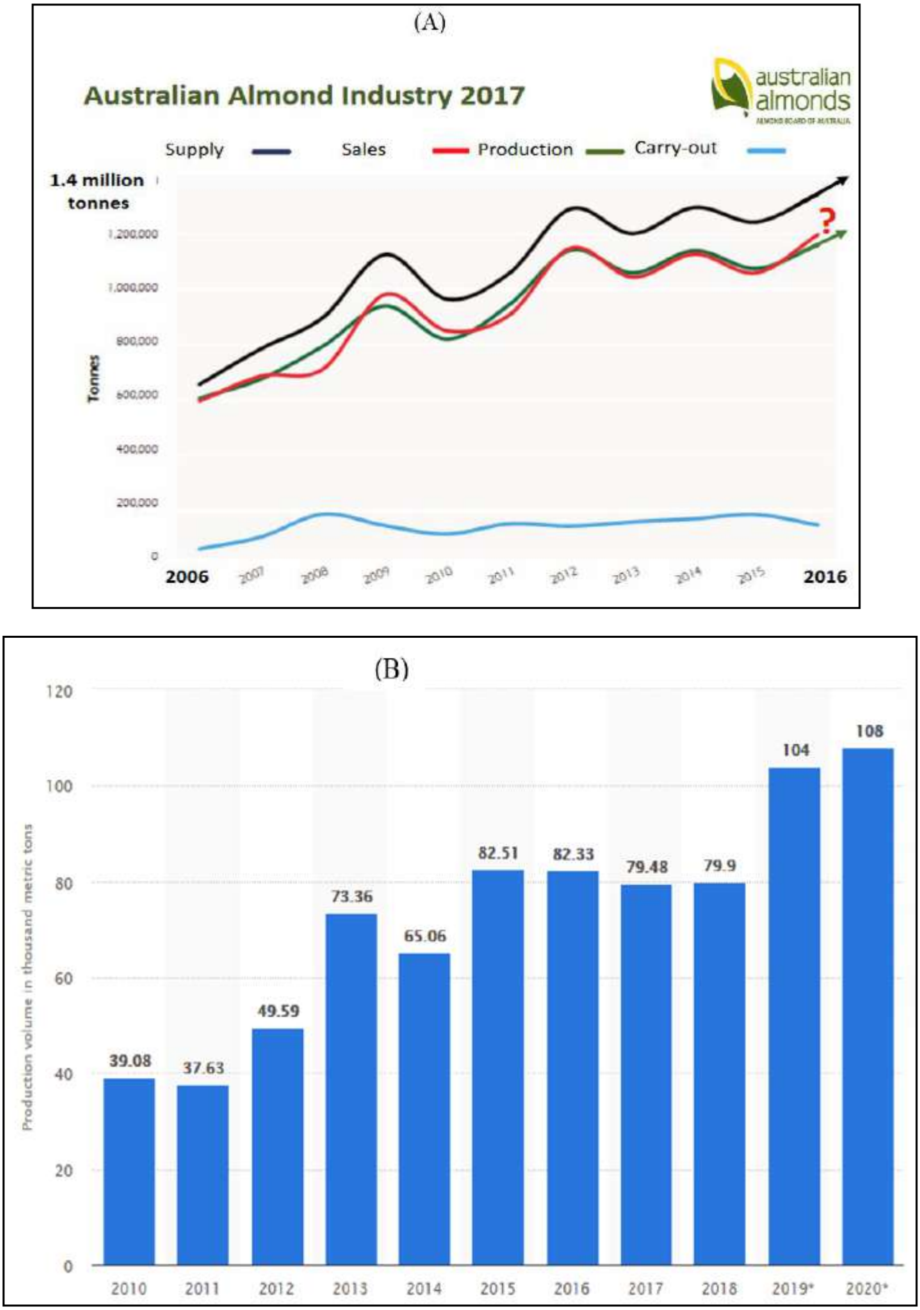


Figure 45. The trend of the almond industry in Australia: A) From 2006 to 2016; B) From 2010 to 2020 (in terms of 1000 tons)

5.2. Almond Experience in Italy

The experience of almonds in Italy shows that the country has not had a successful almond industry. However, good cultivars, especially the original self-compatible cultivars, have come from this country. Therefore, one of the important challenges in almond cultivation in the country is the existence of orchards established as seedlings. Therefore, in these types of orchards, most of the trees, each of which is a genotype, are early flowering and are often damaged by late spring frosts. Due to the non-uniformity of the nuts, in the years that the fruit is produced, the nut is not produced with quality and quantity. In addition, orchard operations such as training and pruning, nutrition and crop harvesting (non-synchronization of crop ripening, sorting, packaging, etc.), etc. are difficult (Figure 46). The experience of the Italian cultivation industry in Figures 47 and 48 shows that these types of orchards cannot compete with advanced almond cultivations (using the right cultivars and rootstocks, applying technical knowledge and technology) in countries like the United States, Australia, and Spain. These factors have largely reduced Italy's almond industry's international market share over the past decades in terms of production and area harvested. However, there is still a strong "traditional almond system". This traditional system has developed around local, not-so-desirable cultivars, and old traditional horticultural systems that have made it impossible to convert them to new and technical horticultural systems (Figure 52).

Figure 46. An example of almond orchards in Italy is old traditional gardening with low productivity

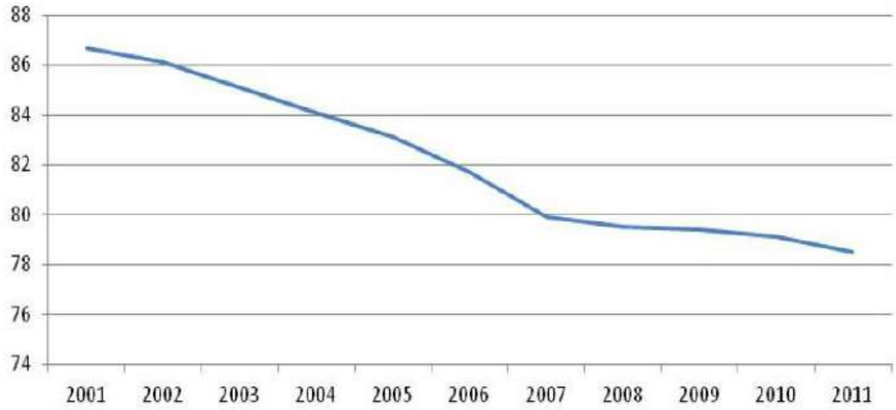


Figure 47. Area harvested (per thousand hectares) of almond orchards in Italy over a decade (2001-2011) (faostat.fao.org)

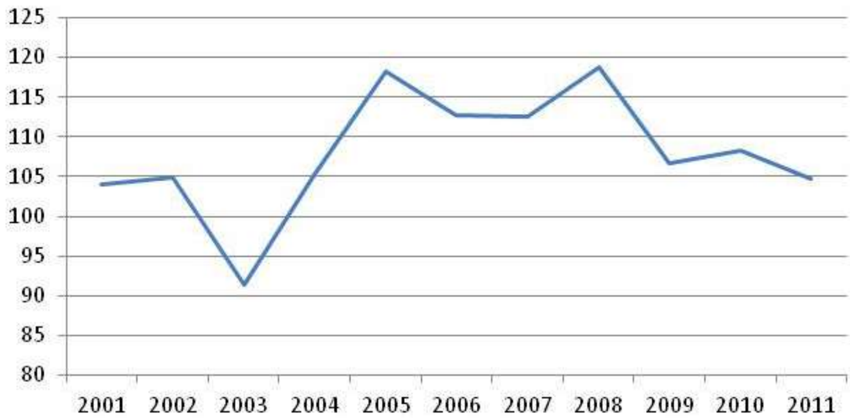


Figure 48. Production (per thousand tons) of almond orchards in Italy over a decade (2001-2011) (Faostat.Fao. Org)

Based on the experiences of some almond-growing countries in the world, we conclude that the traditional old cultivation and seedlings of most orchards in countries such as Italy and more or less Iran do not make the crop uniform and also have the potential to produce less. Therefore, with a single calculation, the amount of damage caused by the seedlings of most orchards and as a result of the non-uniformity of the crop, which has the potential to produce fewer almonds in Iran has been well mentioned in previous explanations

5.3. Experiences in Spain

As an experience, Spain also has almost the same problem of **frost damage** as most countries, which has been able to limit this problem with a plan. In this way, the Almond Breeding Program in CEBAS-CSIC (Consejo Superior de Investigaciones Científicas - Centro de Edafología y Biología Aplicada del Segura) in Murcia, Spain, was initiated in 1971 by examining and screening regional, national and international almond germplasm.In 1981, 81varieties were created, which were evaluated for 10 years. In 1985, the first hybridizing was made by selecting the proposed parents according to the set goals (Dicenta *et al*., 2002a). The main objectives of this program are as follows:

Late flowering and cold resistance: Both traits were used to prevent late spring frost damage.

Self-compatible: This allows growers to cultivate only one cultivar in their orchard (two or more cultivars are not essential). It is not necessary (but recommended) to put a beehive in the garden for pollination. In this type of cultivar, bad weather has a negative effect on pollination. Because in this method, a cultivar is cultivated and a pollinizer cultivar is not necessary (Dicenta *et al*., 2000). In addition, cultivating a self-compatible cultivar in terms of pollination means happiness for almond growers, because garden costs are reduced (a combination of several cultivars is not cultivated) (Dicenta *et al*., 2002a, Ortega *et al*., 2006). Of course, productivity, good size and good aspects of almond kernels, lack of double kernel and resistance to fungal diseases were also of great importance. Since 1995, in order to prevent late spring frosts, goals have been focused on delaying the flowering of cultivars (late flowering cultivars). This is because almonds are not only produced in traditional areas that are damaged year by year due to late spring frosts but also new and colder areas are discovered for production. Today Spain has been able to cultivate almonds in orchards in areas where production is now largely lost due to late spring frosts, using late-flowering cultivars from the 1971 breeding program. It also provides high-risk freezing areas in cold regions where almond cultivation was previously unimaginable due to frost (Figure 51).

The experience of Spanish growers with regard to extension recommendations using suitable cultivars and the establishment of orchards based on technical principles shows a record 15% increase in yield in 2019. The report is based on estimates by the National Association of Producers of Spain, it should be noted that Spain is the second-largest producer of almonds in the world after the United States (Figure 49 and Figure 50).

Figure 49. View of the new almond orchard established with bred cultivars from the Almond Breeding Program at CEBAS-CSIC (Consejo Superior de Investigaciones Científicas - Centro de dafología y Biología Aplicada del Segura). It was initiated in Murcia, Spain in 1971(Boutreux, 2018).

Figure 50. The crop harvest from the new orchard with new cultivars from almond breeding program in Spain

Figure 51. An example of the time when almonds bloom in Spain (in terms of flowering time, the early flowering variety)has a green fruit. But in contrast to the late flowering variety, it has just started flowering. Images were taken simultaneously in an orchard.

5.4. Experiences of French

For the past 40 years, researchers at INRA (French National Agricultural Research Institute) have studied the local almond population and collected important almond germplasm. Foreigners also entered the breeding program from California, Europe and Tunisia. In total, the current almond collection, including 245 almond genotypes, is stored at INRA's experimental station, where efforts are made to select late-flowering almond cultivars to avoid the risk of spring frosts, along with other qualities needed by almond markets. Eventually, Ferragnès and Ferraduel created a cross between AI (Italian cultivar) and Cristomorto (old French cultivar), which are very late and self-incompatible, and have become very popular since their emergence in the 21st century. Recently, ongoing efforts to improve self-compatible cultivars in France have introduced two varieties of late-flowering but self-compatible almonds, Laurent and Mandalin, which have entered the development of monoculture orchards (monoculture) because these cultivars do not need pollinizer.

5.5. Moroccan experiences

Morocco has also used these two Ferragnès and Ferraduel to revolutionize its almond-growing industry, increasing its use from

1.45 million in 2008 to 3.2 million in 2012 (Figures 52). In this way, they controlled the risk of frost to some extent. Recently, two varieties of French late-flowering almonds, Lauren and Mandalin (self-compatible) have also been used to establish monoculture orchards. Thus, nursery plants of these cultivars increased from 78,000 plants in 2010 to 110,000 plants in 2012, which represents a 41% increase over a period of 2 years. Also, Moroccan researchers have conducted joint research with countries. France and the United States, in particular, are studying the genetic diversity of the Moroccan almond population to obtain almond cultivars with highly desirable orchard traits that are resistant to pests and diseases. These types of cultivars contribute to the health of the environment and the health of consumers in the community.

Figure 52. Traditional almond seeding (right) and modern(left) orchards almond in Morocco

5.6. Tunisian experiences

Almond production in Tunisia is based on the use of compatible local cultivars such as Sfaxien and Achaak cultivars and traditional management practices that have minimal use of agricultural inputs (subsistence horticulture) (Figure 53). These almond production areas include a humid climate zone in northern Tunisia, with an average annual rainfall of more than 500 to 700 mm, and a semi-arid climate zone in central Tunisia that receives about 200 mm of rainfall annually. In Tunisia, there are about 20 million almond trees that cover more than 250,000 hectares. Most Tunisian products are sold locally. Unfortunately, almond cultivation in Tunisia is a lower-income crop due to very low yields per hectare and unfavorable weather conditions. However, Tunisian production has recently been established using breeding imported cultivars from France such as Ferragnès and Ferraduel and self-compatible Tuono from Italy. These new orchards have increased production capacity (Figure 53). In addition, due to the early ripening of the fruit, it can be attractive to the European market. In this way, the Tunisians have been able to create good progress in their almond industry.

Figure 53. Traditional almond seedling orchard (right) and Modern almond orchard with improved varieties in Tunisia (left)

5.7. Indian experiences

Almonds in India were first introduced to Kashmir by Persian immigrants in the 16th century, despite the region's great potential, the product failed on a commercial scale such apples. It is produced in India with an area of 23.81 thousand hectares with a production of 11.47 thousand tons. The average yield of almonds (in shell) is half a ton per hectare in India compared to the United States (3.04 tons per hectare). However, domestic demand is growing every year, and as a result, imports in 2017 increased by 7% to US$ 600 million. Considering the nutritional and health value of almonds (almonds as an ingredient in many products, including health, drinks, biscuits, ice cream, etc.), Indians seem to have made them the world's largest consumer of almonds in recent years. Therefore, India can be considered a huge market for Iranian almonds if we have good planning in competition with competitors. India has been able to increase production and productivity by adopting development policies, including the selection of suitable and compatible cultivars and various methods and technologies appropriate to the production area. In this regard, the Central Institute of Temperate Horticulture (CITH) and the State Agricultural Universities (SAU) recently identified the development and cultivation of cultivars and technologies appropriate to the region, yielding 0.92 ton/ha in Jammu and Kashmir increased to about 3 tons/ha, which is much higher than the global average (1 ton/ha) and almost equal to the US yield (3.0 ton/ha) (Figure 54).

Figure 54. Traditional almond seedling orchard(left) and modern almond orchard with improved varieties in Kashmir region (right)

5.8. Turkey experiences

Turkey has significant potential for almond production. However, most almond orchards in Turkey are seedlings. For this reason, the local almond nuts available in the markets have a double kernel, small and large fruits, dark and light-colored kernels, and a mixture of bitter and sweet almonds. Thus, in recent years, Turkey has been importing almonds (Kaska *et al.*, 1999). According to the average almond production in the last three years, Turkish almond production was 52790 tons and it was placed eighth in the world (FAO, 2011). The Mediterranean regions of southeastern Anatolia and the Aegean have the potential to grow modern almonds in Turkey (Figure 55). The Southeastern Anatolia Project (GAP n) is the largest project to develop orchards under Turkey's pressurized irrigation system, covering about two million hectares of arable land. In recent years, modern almond orchards have been established in the area as part of the Southeastern Anatolia Project (GAP n). The results of the study indicate the success of almond cultivars (late-flowering foreign cultivars) in the GAP region. Because spring frosts are a limiting factor for almond cultivation in Turkey, late flowering is a very important trait for almond cultivars. Turkish almond cultivars are classified as hard-shell almonds and are incompatible. Growers are not interested in local almond cultivars. Self-compatible and late-flowering almond cultivars are preferred in orchards at lower costs in crop management and higher yields. For this reason, paying attention to the type of almond cultivar is one of the main factors in almond cultivation programs in Turkey. Recently, they have been focused on their self-compatible and late flowering cultivars to solve both the problem of spring frosts and the problem of pollination. In this regard, with the support of the government, research projects are underway to improve the self-compatible and late-flowering cultivars (pilot's orchards with self-compatible and late-flowering cultivars).

Figure 55. Traditional almond seedling orchard (right) and modern almond orchard with improved varieties in the southeastern region of Anatolia (left)

5.9. Iran experiences

In this regard, in addition to late flowering and self-compatible in terms of pollination, the compatibility of almond cultivars in different regions is also important. In Iran, the study of climatic and regional compatibility of 60 cultivars and the promising genotypes of domestic and foreign almonds in the form of a development research study project in ten almond-growing provinces such as Khorasan Razavi, Chahar Mahal and Bakhtiari, East Azerbaijan, Fars, Markazi ,Zanjan, Alborz,West Azerbaijan,Tehran and Hamedan provinces, has started on the GF677 rootstock for the uniformity of the established orchards. Work is on the process as planned. It is hoped that adaptable cultivars for each region of the country will be identified and used in the development program. This is because almond cultivars respond differently to climate change. For example, Nonpareil almond is the most widely planted in California, accounting for 75% of US almond cultivation. However, this cultivar has not been well-adapted to the condition of Iran since the late 1940s and has not become more common. The buds fail and the tree takes on the appearance of a broom. Also, some domestic cultivars such as the Azar cultivar have been introduced as late flowering in cold regions such as Azerbaijan, but in some regions of the country such as Yazd province, it shows early flowering and blooms almost simultaneously with native cultivars. Therefore, in order to solve the unintended problems of cultivars that are in the development of almonds and do not show adaptation in some areas, the adaptation program of 60 cultivars and promising genotypes in different provinces until determining the most compatible cultivar for each region is being.

Examples of promising cultivars and genotypes of almonds used in the research and development plan of almonds in different regions of the country are presented in Figure 56 and 57 A,B,C.

Figure 56. Example of almond flowering time in Iran in 2020, including more than 100 cultivars and genotypes. In terms of flowering time, all cultivars and genotypes have blossomed and were in the green fruit phase (green arrow), while some were late flowering and fresh flowering has started (white arrow). Simultaneous images were taken in the collection of cultivars and genotype in Karaj.

(A) **Cold-resistant genotypes on 16 March ,2022 with a negative temperature drop of 4°C in** Karaj

(B) **A case example of the occurrence of frostbite on April 7 and 8, 2022 in Chaharmahal and Bakhtiari province with a temperature drop of -2 to -5 °C based on different regions of Chaharmahal and Bakhtiari province**

(C) Sample of improved almonds under Compatibility evaluating of almond Cultivars and genotypes in the National project

Figure 57 A, B, C. Samples of almond cultivars and promising genotypes under evaluating in national project in deferent regions of Iran

6. Density of Orchards

6.1. Experiences of Spain, Australia and Turkey

The Spaniards have not only made changes in their country's almond industry by introducing self-compatible cultivars, especially late flowering ones, and suitable rootstocks but have also sought to build dense almond orchards using dwarf rootstocks. In this way, their almond industry will peak. Of course, the use of dwarf rootstocks in many parts of the world, including Spain, Australia, Turkey, etc., for the establishment of dense almond orchards has recently begun. In this system, planting is done using dwarf rootstocks for the establishment of high-density almond orchards. In this regard, several examples of almond orchards with dense cultivation using these dwarf rootstocks are shown in Figures 58 and 59.

Figure 58. Marinada/Rootpac 20, Marinada/MB 1-37, Marinada / Rootpac 40, and Marinada/GF677 (clockwise from top left)

Figure 59. Vairo - Pruned vase, unpruned vase, minimal pruned central leader, heavier hedge prune, minimal hedge prune, intensive pruned central leader (clockwise direction from top left) (Rosenzweig, 2014)

7. Conclusion and Recommendations

Almond production has many challenges, in Iran but the low quantity and quality of the product are the main challenges of almonds. These challenges have many components, but three of them are great priorities as follows: lack of proper pollination management, seeding of most almond orchards and thus, non-uniformity of the product which contributes to lower production potential and finally, spring frost problems.

Based on the experiences of some almond-growing countries in the world, we conclude that the traditional old cultivation and seedlings of most orchards in countries such as Italy, more or less Iran and so on, do not make the crop uniform and also have the potential to produce less.

Also, spring frost is one of the major problems in growing almonds. For example, the compensation paid for frost damage in almonds during the last 7 years in Iran is equal to 24311995070 Rials, which is the highest compensation for Chaharmahal and Bakhtiari, East Azerbaijan, Khorasan Razavi provinces.

Despite the good relative advantage of almonds, there are problems with the production of almonds that must be overcome. In this regard, the use of world experiences can be used to solve problems. Thus, in this publication, the trend of the almond industry in Iran in comparison with the other countries with an emphasis on major problems and in terms of world experiences on how to overcome problems and improve the production process for use in the country's almond industry is examined and reviewed. Attention to the following factors is emphasized and suggested:

1- To reduce the risk of frost, invest in and pay attention to the projects of breeding and introducing late-flowering, self-compatible and fruitful varieties with the desired quality.

2- To increase fruit set (increase yield) in the country's almond orchards, introduce the role of pollination management and self-compatible fruitful cultivars with good fruit by informing through the formation of training and extension workshops and creating pilot orchards to familiarize growers with the exchange of experiences and technical information. To increase the quality and quantity of the product by introducing good quality and fruitful varieties.

3- Pay attention to the role of technical knowledge transfer and its promotion for the grower to increase production and quality improvement.

4- Supporting the private sector to invest in the development of the country's almond growing industry in various aspects (implementation of important projects for the development of modern almond orchards in the country by using modern technology and supporting investors in industry and processing, packaging and marketing).

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