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## Genetic Diversity in Apricot

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### 1. Introduction

Apricot is a fruit species adopted to a wide geographical areas (De Poerderlé, 1788; Loudon, 1838; Arakelyan, 1968; Mehlenbacher et al. 1991; Huxley, 1992; Butner, 2001). 173 years ago, Loudon (1838) was first to mention that wild apricots with different shades of pink flowers had been used as ornamental purpose for centuries. Nowadays commercial production areas of apricots are still very limited with a small number of varieties, although they spread across a wide area all over the world. Looking at the statistics, the production value has been observed to show upward trend by years. This increase in production is closely related with breeding studies in different countries. Breeding programs were modified generally according to consumer's demands and also some subjects such as resistance to diseases (Sharka, Monilinia etc.) and frost damages, determination of self-(in)compatibility.

Germplasm collection and characterization is an early essential stage to initiate a breeding program for diversity. Traditionally germplasm collection and characterization had been done describing phenological, pomological and morphological characteristics such as tree vigor and growth habit (Perez-Gonzales, 1992; Badanes et al. 1998; Asma & Ozturk, 2005), fruit quality features (Rehder, 1940; Bailey & Hough, 1975; Audergon et al. 1990; Souty et al. 1990; Crossa-Raynaud & Audergon, 1991; Parolari et al. 1992; Bassi & Bartolozzi, 1993; Badanes et al. 1998; Gurrieri et al. 2001; Ledbetter & Petterson, 2004; Asma & Ozturk, 2005; Ruiz & Egea, 2008; Milosevic et al. 2010), leaf (Bailey, 1916; Hou, 1983; Rostova & Sokolova, 1992), stone (Felföldi et al. 2009; Malik et al. 2010), flower (Rodrigo et al. 2006; Yilmaz & Paydas-Kargi, 2010), stigma and stylus (Viti et al. 2000) and pollen (Dezhong et al. 1995; Davarynejad et al. 2005; Arzani et al. 2005; Asma, 2008) comparing and combining the results of characterization researches published by different groups is a difficult task since different variety of morphological, phenological and pomological characteristics have been assessed by the research groups. International UPOV and IPGRI criteria was created in order to overcome this unrequired situation and to enable researchers use common descriptor characteristics.

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In the last two decades, molecular studies have been integrated into the conventional germplasm characterization researches (Battistini & Sansavini, 1991; Badanes et al. 1996; Mariniello et al. 2002; Hurtado et al. 2001, 2002; Hormaza, 2002; Vilanova et al. 2003; Geuna et al. 2003; Zhebentyayeva & Sivolap, 2000; Zhebentyayeva et al. 2003; Sanchez-Perez et al. 2005; Romero et al. 2003, 2006; Rao et al. 2008; Yilmaz, 2008; Akpinar et al. 2010) and genetic diversity in apricot. Recent studies show that this genetic diversity originated in Central Asia and transferred to Middle Asia and Caucasia. Later on, the apricot was taken to Europe, and recently spreaded from Europe to North America and the rest of world.

2. Systematic and eco-geographical groups of apricot

Apricot belongs to *Prunus* genus. Some systematicians created different sections under *Prunus* genus and *Prunophora* sub-genara or Rosaceae family and Prunoideae sub-family (Table 1). American apricots are seen *Armeniaca* sub-section and named *Armeniaca vulgaris* Lam. (Bailey & Hough, 1975).

Bailey (1916) (Ledbetter, 2008)		Rehder (1940) (Ledbetter, 2008)	
Genus	<i>Prunus</i>	Genus	<i>Prunus</i>
Sub-genera	<i>Prunophora</i> (plums, prunes & apricot)	Sub-genera	<i>Prunophora</i>
<i>Prunus armeniaca</i> L.		Sections	Euprunus (European/ Asian Plums)
Var. <i>pendulata</i> Dipp.		Pronocerasus (North American plums)	
Var. <i>variegata</i> Hort.		Armeniaca (Apricots)	
Var. <i>sibirica</i> Koch		Armeniaca (Apricots)	
Var. <i>mandshurica</i> Maxim.		<i>P. brigantina</i> Vill.	
Var. <i>Ansu</i> Maxim.		<i>P. mandshurica</i> Maxim.	
<i>P. mume</i> Sieb. & Zucc.		<i>P. sibirica</i> L.	
Var. <i>Goethartiana</i> Koehne.		<i>P. armeniaca</i> L.	
Var. <i>albo-plena</i> Hort.		<i>P. mume</i> Sieb. & Zucc.	
Other wild forms		<i>P. dasycarpa</i> Ehrh.	
<i>laciniata</i> Maxim.		<i>P. armeniaca</i> L.	
<i>microcarpa</i> Makino		<i>P. armeniaca variegata</i> Schneid.	
<i>viridicalyx</i> Makino		<i>P. armeniaca pendula</i> Jaeg.	
<i>cryptopetala</i> Makino		<i>P. armeniaca Ansu</i> Maxim.	
<i>P. brigantiaca</i> Vill.		<i>P. mume</i> Sieb. & Zucc.	
<i>P. dasycarpa</i> Ehrh.		<i>P. mume alba</i> Rehd.	
		<i>P. mume Alphandii</i> Rehd.	

Lingdi & Bartholomew (2003) (Ledbetter, 2008)			
Family	Rosaceae	<i>P. mume albo-plena</i> Bailey	
Subfamily	Prunoideae	<i>P. mume Pendula</i> Sieb	
Genus	Armeniaca (Apricots)	<i>P. mume tonsa</i> Rehd.	
<i>Armeniaca vulgaris</i> L.		Bortiri et al. (2002) (Ledbetter, 2008)	
Var. <i>vulgaris</i> L.		Sections	<i>Penarmeniaca</i>
Var. <i>zhidanensis</i> Qiao & Zhu			
Var. <i>ansu</i> Maxim		<i>Penarmeniaca</i>	
Var. <i>meixianensis</i> Zhang		<i>Prunus fremontii</i> S. Wats.	
Var. <i>xiongyueensis</i> Li		<i>Prunus andersonii</i> A. Gray.	
<i>Armeniaca limeixing</i> Zhang & Wang		Hayashi et al. (2008)	
<i>Armeniaca sibirica</i> L.		Traditional Japanese classification	
Var. <i>sibirica</i> L.		(Mega et al., 1988; Horiuchi et al., 1996)	
Var. <i>pubescens</i> Kostina			
Var. <i>multipetala</i> Liu & Zhang			
Var. <i>pleniflora</i> Zhang			
<i>Armeniaca holosericea</i> Batal.		<i>Prunus mume</i>	
<i>Armeniaca hongpingensis</i> Li		For fruit production	
<i>Armeniaca zhengheensis</i> Zhang & Lu		For ornamental “kei”	
<i>Armeniaca hypotrichodes</i> Cardot		Yabai	
<i>Armeniaca dasycarpa</i> Ehrh.		Yabai sub-groups	
<i>Armeniaca mandshurica</i> Maxim.		Naniwa sub-groups	
Var. <i>mandshurica</i> Maxim.		Benifude sub-groups	
Var. <i>glabra</i> Nakai		Aojiku sub-groups	
<i>Armeniaca mume</i> Sieb. & Zucc.		Koubai	
Var. <i>mume</i> Sieb.		Koubai sub-groups	
Var. <i>pallescens</i> Franc.		Bungo	
Var. <i>cernua</i> Franc.		Bungo sub-groups	
Var. <i>pubicaulina</i> Qiao & Shen		Anzu sub-groups	

Table 1. Apricot systematics according to various researchers

Leaf characteristics were accepted the most important criterion for apricot systematic by various researchers. Bailey (1916) examined the leaves emerged from dormant buds. Rehder (1940) used leaf shape and pubescence for classification of species. Chinese botanists utilized leaves in parallel Western researchers. However, Japanese researchers considered flower and branch color and flower size in Japanese apricots (*Prunus mume*) which is an ornamental plants for Traditional Japanese classification (Mega et al. 1988; Horiuchi et al. 1996). *Prunus fremontii* which is in *Penarmeniaca* section and reported in some studies (Bortiri et al. 2001, 2002) along with the desert dwelling species *Prunus andersonii* A. Gray. *Prunus fremontii* can be hybridized freely with other apricot species and differs from them (Ledbetter, 2008).





a. *Prunus armeniaca* var. *ansu* ([www.flickr.com](http://www.flickr.com))  
b. *Prunus mume* ([http://commons.wikimedia.org/wiki/File:Prunus\\_mume\\_Yaekanko.jpg](http://commons.wikimedia.org/wiki/File:Prunus_mume_Yaekanko.jpg))  
c. *Prunus brigantina* (<http://luirig.altervista.org/cpm/albums/bot-042/001-prunus-brigantina.jpg>)  
d. *Prunus armeniaca*  
e. *Prunus mandshurica* (<http://www.lawyernursery.com>)  
f. *Prunus sibirica* ([http://www.agroatlas.ru/en/content/related/Armeniaca\\_sibirica/](http://www.agroatlas.ru/en/content/related/Armeniaca_sibirica/))

Fig. 1. Different apricot species

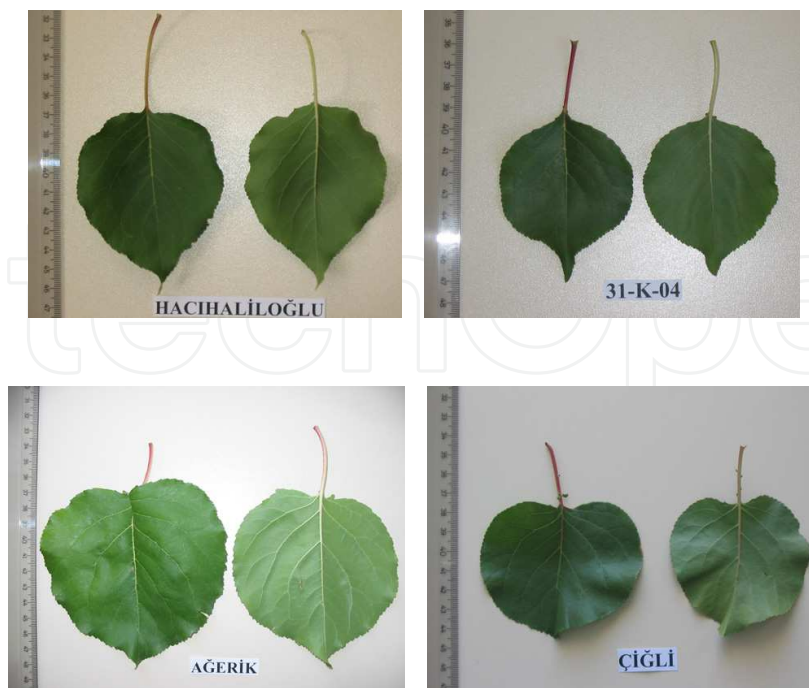


Fig. 2. Leaf shapes in *Prunus armeniaca* in Irano-Caucasian eco-geographical group (Turkish apricots - Yilmaz, 2008)

Apricot has  $2n=16$  chromosomes. Wide variations emerged in apricots because of seed propagation and growing in different ecological areas in time. Therefore, the systematicians reported that 6-8 eco-geographical groups and 13 regional sub groups occurred.

- a. Central Asian eco-geographical group (Kostina, 1969)
  - Fergana regional sub-group (Bailey & Hough, 1975)
  - Upper Zeravshan regional sub-group (Bailey & Hough, 1975)
  - Semerkand-Shahrasiabz regional sub-group (Bailey & Hough, 1975)
  - Horezm regional sub-group (Bailey & Hough, 1975)
  - Kopet-Dagh regional sub-group (Bailey & Hough, 1975)
- b. Irano-Caucasian eco-geographical group (Kostina, 1969)
  - Iran-Caucasus regional sub-group (Mehlenbacher et al. 1991)
  - Dagestan regional sub-group (Mehlenbacher et al. 1991)
  - North Africa regional sub-group (Mehlenbacher et al. 1991)
- c. European eco-geographical group (Kostina, 1969)
  - Western European regional sub-group (Layne et al. 1996)
  - Eastern European regional sub-group (Layne et al. 1996)
  - Northern European regional sub-group (Layne et al. 1996)
- d. Dzhungar-Zailig eco-geographical group (Kostina, 1969)
  - Dzhungar regional sub-group (Mehlenbacher et al. 1991)
  - Zailig regional sub-group (Mehlenbacher et al. 1991)
- e. Northern China eco-geographical group (Bailey & Hough, 1975)
- f. Eastern China eco-geographical group (Bailey & Hough, 1975)
- g. Tibet eco-geographical group (Bailey & Hough, 1975; Asma, 2011)
- h. Northeast China eco-geographical group (Bailey & Hough, 1975; Asma, 2011)



The oldest and richest in diversity is the Central Asian group which includes local apricots from Central Asia, Xinjiang, Afghanistan, Baluchistan, Pakistan, and Northern India (Kashmir). This group is mostly self-incompatible and characterized with medium sized fruits and they have a tendency to bloom late spring. The secondary gene center of apricot is the Irano – Caucasian group which extends from Armenia, Georgia, Azerbaijan, Dagestan, Iran, Iraq, Syria, Turkey, to North Africa, and even to Spain and Italy. They are generally self-incompatible, but on contrary, they produce large fruits and blooms earlier than apricots of Central Asia and needs lower chilling hours. Apricots of North American, South African, and Australian are classified as the European group and this group was originated from the apricots of Armenia, Iran, Turkey, and other Arab countries. Apricots of this group are self-compatible, fruits are more precocious and the trees need low chilling. The Dzhungar-Zailig group with mostly small fruits includes selections from regions of Dzharzskent, Taldy-Kurgan, Kazakhstan, and Xinjiang (Mehlenbacher et al. 1990; Layne et al. 1996; Faust et al. 1998). Later, two major groups proposed by Bailey & Hough (1975), the Northern China group that includes forms of *Prunus mandshurica* and *Prunus sibirica*, and the Eastern China group that includes forms of *Prunus ansu* (Romero et al. 2003). In addition, some researchers mentioned two more groups named Tibet and Northeast China. While Tibet eco-geographic group includes forms of *Prunus armeniaca* var. *holosericea*, Northeast China eco-geographic group includes varieties and types of *Prunus armeniaca*, *Prunus sibirica* and *Prunus mandshurica* (Bailey & Hough, 1975).

The Central Asian and Irano-Caucasian including Turkish and Iran cultivars eco-geographical groups show the richest phenotypic variability, while European group including cultivars grown in North America, Australia and South Africa is to exhibit the least diversity (Mehlenbacher et al. 1991; Halasz et al. 2010).

### 3. Origin and spread of apricot to the world

According to the famous Russian Botanist Vavilov (1951), there are three important regions as origin of apricots although Armenia had been supposed apricot's origin and named as *Prunus armeniaca*, previously. These are;

- a. The Chinese center (China and Tibet)
- b. The Central Asian center (from Tien-Shan to Kashmir)
- c. The Near-Eastern center (Iran, Caucasus, Turkey)

Also Vavilov (1951) reported that the Near-Eastern center could be secondary gene center because of cultured varieties and absence of wild apricot forms (Bailey & Hough, 1975; Asma, 2011).

The spread of apricots from Central Asia to the rest of world are explained by three different views. The first of these, dried apricot fruits and stones of natural apricot flora in Fergana Valley which is at the border of Uzbekistan, Tajikistan, and Kyrgyzstan and piedmont of Hind Kush and Tian Shan mountains were brought to Anatolia by soldiers on Iran and Transcaucasus during organized Asia campaigns by the Great Alexander in BC 334. Later on, apricot was moved to Europe from Anatolia during the Roman-Persian wars in BC 1 (Layne et al. 1996). The second view; apricot was brought to Anatolia by merchants from China and Center Asia on famous Silk Road, and then Roman soldiers carried apricot to

Italy from Anatolia (Bailey & Hough, 1975). The third view is that Romans removed apricot to west during their expeditions to seize the Near East (Syria, Iran, and Caucasus) in BC 2 (Layne et al. 1996). Apricot gradually spreaded to Africa on Mediterranean countries and Middle East, it was also carried to Balkans by Ottomans in XV. and XVI. century (Suranyi, 1999). Apricot was taken to Southern Europe from Eastern Europe countries (Asma, 2011), to England in 1524 or 1548 from Italy. It was removed to America continent by the Spanish in 1626 (Faust et al. 1998).

4. Apricot production of the world

Despite we observe rich distribution of apricot through the world, the commercial production areas are limited. The majority of production is done in Mediterranean countries and also in Iran, Pakistan, Uzbekistan, Morocco, Algeria, Ukraine and USA (Romero et al. 2003).

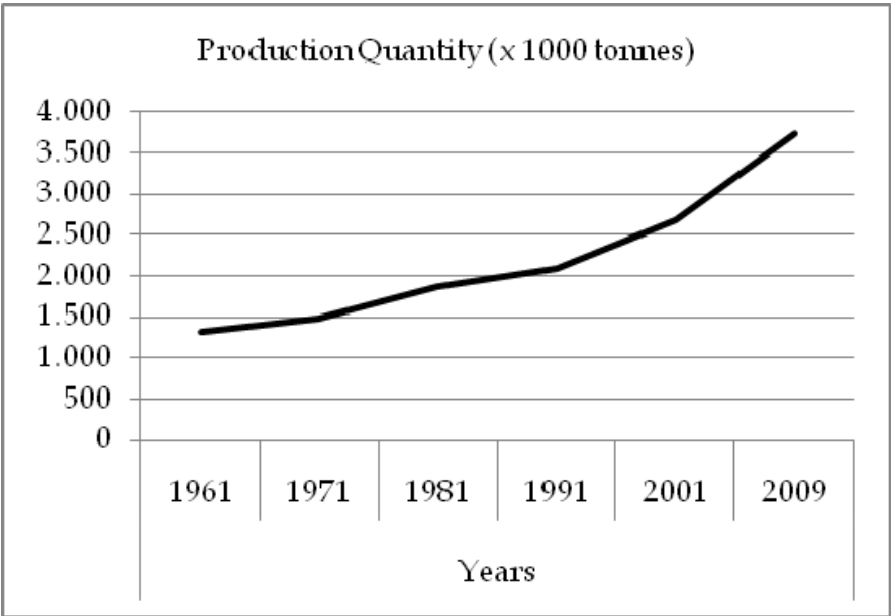


Fig. 3. World apricot production from 1961 to 2009 (FAOSTAT, 2011)

Analyzing the data by years from 1961 until 2009, we observe that the amount of production in the world have increased on a regular basis. During the last 50 years 1.317.607 tons per year production reached about 3.728.083 tons (Fig 3). Despite to this increase in the 50 years amount of production is actually low due to the limited capabilities of adaptation to different environments, limited numbers of variety, self-incompatibility, frost damage, susceptibility to Sharka and Monilinia (*Sclerotinia laxa* Aderh et., Ruhl.).

Turkey is the leading country at the production of apricots. Turkey with its rich genetic resources and high quality dried apricot cultivars has reached to monopolistic position in the world. In recent years, the farming of dried apricot has increased in China, Pakistan, Iran, Syria, Uzbekistan, Afghanistan, too. Especially the city of Malatya in Turkey (Fig 4) and the surrounding areas of the city provides more than half of production of the country. For this reason, the city, Malatya is called also the apricot capital of the world (Asma, 2007). Apricots have been traditionally a part of life and as a symbol of the city at every point





Fig. 4. Malatya province where is the most apricot produce in the world.



Fig. 5. Apricot is a symbol in Malatya.



(Fig 5). Malatya Apricot Research Station established in the city in 1937 played an important role at the development of apricot farming in the city (Fig 6). The station has a rich collection of 285 apricot accessions of different eco-geographical groups. It is third behind the Nikitsky Botanic Garden in Ukraine and Central Asian Experimental Station of the Institute of Plant Industry in Uzbekistan (Fig 7). The institution host thousands of seedlings obtained from constantly maintained crosses. In 2010, Malatya produced 661.000 tons of fresh apricot. Of the that production 101.000 tons dried apricots were obtained (TurkStat, 2010) (Fig 8).

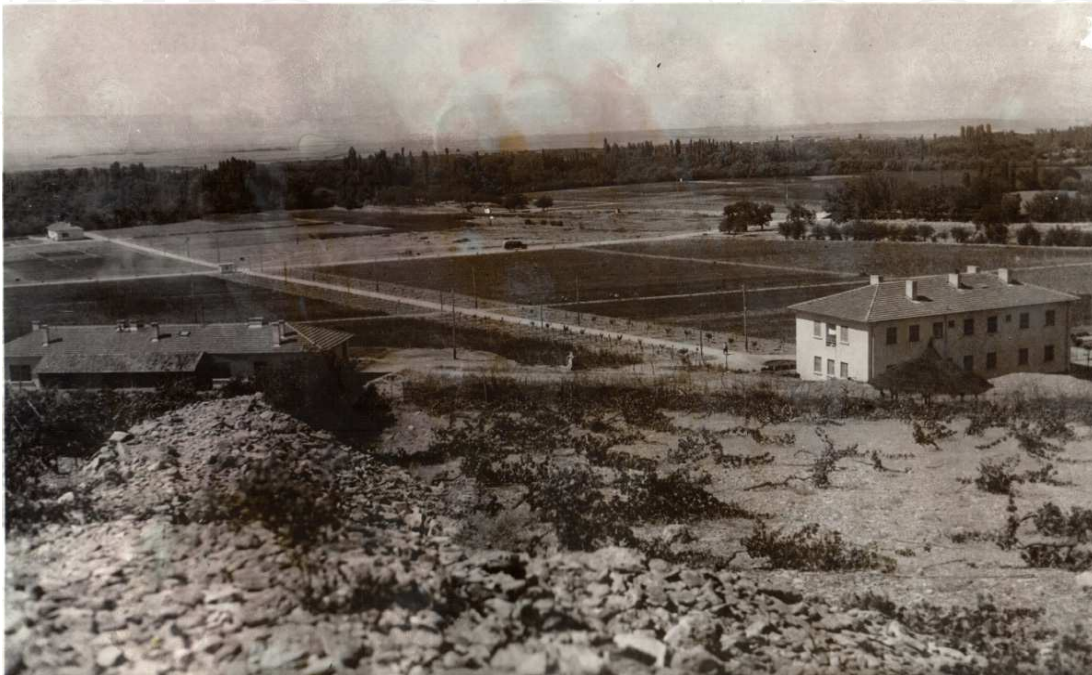


Fig. 6. Apricot Research Station (1937)



Fig. 7. A view of Apricot Genetic Resources Collection Orchard in Apricot Research Station in Malatya / Turkey



Fig. 8. Best apricot competition in Malatya and new apricot cultivar Alkaya for table and dried consumption

Apricot cultivation in the Mediterranean countries generally base on early and middle season table apricots and Spain, Italy and France have authority in the trade of table apricots. USA, South Africa and Australia are producer of dried and flesh apricots. However production of USA decreases sharply.

Apricot rich countries has plenty of genetic diversity due to the production many years with seed. This increase shows that the studies need to be done in apricot. Indeed, in recent years, big, flashy, red-checked with orange flesh and resistant apricot variety has been the target of new development. Especially in Europe and the USA breeding programs released big new cultivars with cheek color of red but because of the low brix and poor flavor the release failed to succeed in the marked.

One of the main priority of apricot breeding programs in the mid of 1990s was to develop cultivars resistant to the late spring frost (Layne et al. 1996; Bassi & Sansavini, 1988). However, unlike almond breeding (Vargas & Romero, 2001), this aim was failed to succeed



(Demirtas et al. 2010). In the wild apricots and germplasm collections the lack of genotypes exhibiting resistance to the late spring frost was the main reason for this fail. But this failure was ignored by producer since apricot is high-profit production and good evaluation of adaptation studies (Occarso, 1977; Durie, 1988; Ogasanovic et al. 1991; Harsanyi, 1991; Ozvardar et al. 1991; Baktir et al. 1992; Bassi et al. 1995; Kaska et al. 1995; Egea et al. 1995; Audergon et al. 1995; Ayanoglu et al. 1995; Paydas et al. 1995; Draganescu & Cociu, 1997; Hofstee et al. 1997; Papanikolaou-Paulopoulou & Poulis, 1997; Yilmaz, 2002; Blanc et al. 2006).

One of the main goals breeding programs was to obtain varieties resistant to *Monilinia* [*Sclerotinia* (*Monilinia*) *laxa* Aderh et., Ruhl] (Cociu et al. 1991; Gulcan et al. 1994; Bassi et al. 1995; Bassi & Audergon, 2006; Guerriero et al. 2006; Nicotra et al. 2006; Acarsoy et al. 2011). Although this ended up with some success, economically important cultivars were not released into market. Using efficient fungusit prevented also *Monilinia* breeding programs.

All of these germplasm used in breeding and molecular genetic studies in recent years drawn towards different targets. The most important of these is Sharka (*Plum pox virus*) disease, unfortunately, which caused great losses (Lopez-Moya et al. 2000; Cambra et al. 2006).

In addition, problems related to self-incompatibility became main problem after Sharka, in terms of ensuring the efficiency of production. In this context, the presence of *S* alleles on behalf of researchers to understand the mechanism of conflict directed to this point.

## 5. Sharka (*Plum pox virus*) resistance in genetic diversity of apricot

Sharka or Plum pox virus (PPV) is the most serious disease of *Prunus* trees. The disease has spreaded throughout many European countries, especially in Mediterranean countries. Resistant cultivars are limited and only some North American cultivars are known to be resistant to the disease. 'Stark Early Orange' (SEO), 'Goldrich', 'Harlayne', 'Stella', and 'Harcot' are the resistant cultivars mostly used as resistant source for breedings (Martinez-Gomez et al. 2000). The resent focus on the disease increased also cruiosty on the source of resistance of American cultivars. It is believed that North American cultivars originated from a limited number of European cultivars. The source of the resistance is unknown. However, recent studies shows that Central Asian apricots is the most likely source of resistant genes in the North American donors. *Prunus mandshurica* was first to be offered as PPV resistance into North American germplasm (Badenes et al. 1996). Zhebentyayeva et al. (2003) showed that 'Harlayne' and 'Goldrich' clusters with native Central Asian cultivars. 'Stark Early Orange', LE 2904, LE 3276, and 'Vestar' are also grouped with native Chinese material on the genetic diversity study (Zhebentyayeva et al. 2003). Hormaza (2002) also demonstrated that Chinese cultivars contributed to the pedigree of 'Stark Early Orange'. The recent research of Zhebentyayeva et al. (2008) shows that cultivars 'Harlayne', 'Goldrich', and 'Stark Early Orange' has genetic similarity with native Central Asian genotypes. The researchers also showed that *Prunus davidiana* alleles in 'Stark Early Orange' and *Prunus mume* alleles in 'Stark Early Orange' and 'Goldrich' pointed out a contribution of these species to PPV resistance as well (Zhebentyayeva et al. 2008).

## 6. S-genotyping in genetic diversity of apricot

Like to other *Prunus* species, apricots show gametophytic self-incompatibility controlled by a single locus with multiple genes, *S*-haplotypes (De Nettancourt, 2001). The *S*-haplotype



contains a female determinant, (*S-RNase*) encoding for a ribonuclease enzyme (McClure et al. 1989), and the recently identified male determinant, *S-haplotype-specific F-box* gene (Entani et al. 2003; Romero et al. 2004; Halasz et al. 2010).

The Irano – Caucasian group are usually self-incompatible whereas European apricots are mostly self-compatible (Halasz et al. 2005; Kostina, 1970). Mehlenbacher et al. (1991) stated Central Asian apricots are also mostly self-incompatible.

Cross-incompatibility between a pair of cultivars occurs frequently self-incompatible species. Cross-incompatibility was observed among the North American cultivars, Goldrich, Hargrand and Lambertin No.1 (Egea & Burgos, 1996), and also among giant-fruited Hungarian apricots (Szabo & Nyeki, 1991; Halasz et al. 2010). Halasz et al. (2010) determined total 12 cross-incompatibility groups between Irano-Caucasian eco-geographical groups (Turkish apricots) and European eco-geographical groups (Hungarian and North American apricots) (Table 2).

Cross-incompatibility groups	Cultivars	S-genotype
I	Goldrich, Hargrand, Lambertin No.1	S <sub>1</sub> S <sub>2</sub>
II	Cologlu, Kadioglu, Seftalioglu, Cegledi orias, Ligeti orias	S <sub>8</sub> S <sub>9</sub>
II	Iri Bitirgen, Moniqui	S <sub>2</sub> S <sub>6</sub>
IV	Artvin PA, Priana	S <sub>2</sub> S <sub>7</sub>
V	Alyanak, Ziraat Okulu	S <sub>2</sub> S <sub>8</sub>
VI	Dortyol-4, Sebbiyiki	S <sub>2</sub> S <sub>19</sub>
VII	Sakit-3, Tokaloglu Izmir	S <sub>3</sub> S <sub>19</sub>
VIII	Cataloglu, Ozal, Soganci	S <sub>6</sub> S <sub>9</sub>
IX	Zerdali No.1, XI Zerdali	S <sub>6</sub> S <sub>12</sub>
X	Ordubat, X2 Zerdali	S <sub>7</sub> S <sub>12</sub>
XI	Adilcevaz-5, Hacihaliloglu, Kabaasi, Kamelya, Zerdali No.2	S <sub>9</sub> S <sub>13</sub>
XII	Shalakh (Aprikoz), Voski	S <sub>11</sub> S <sub>13</sub>
XIII	Levent, Sakit-1	S <sub>6</sub> S <sub>19</sub>
XIV	Cekirge 52, X3 Zerdali	S <sub>9</sub> S <sub>20</sub>
0: Universal pollen donors	Canakkale (S <sub>c</sub> S <sub>c</sub> ), Ethembey (S <sub>c</sub> S <sub>8</sub> ), Karacabey (S <sub>c</sub> S <sub>2</sub> ), Mektep (S <sub>c</sub> S <sub>8</sub> ), Pasa Mismisi (S <sub>c</sub> S <sub>8</sub> ), Sam (S <sub>c</sub> S <sub>2</sub> ), Yerli Izmir (S <sub>c</sub> S <sub>7</sub> )	

Table 2. Cross-incompatibility groups of apricot (Halasz et al. 2010; Egea & Burgos, 1996; Halasz et al. 2005)

To date, 21 *S-RNase* alleles are known in European apricots, 20 of which (S<sub>1</sub>-S<sub>20</sub>) code for self-incompatibility and one (S<sub>c</sub>) allowing self-compatibility (Burgos et al. 1998; Halasz, 2007; Halasz et al. 2005, 2007) and recently it was confirmed that S<sub>c</sub> haplotype is a pollen part mutant of S<sub>8</sub> haplotype (Halasz et al. 2007). Beside, some additional S-alleles have been also identified in Chinese cultivars (Wu et al. 2009; Halasz et al. 2010).

A gradually decreasing allele number was detected in apricot landraces from China to Western Europe, with some allelic exclusivity occurring in certain geographic areas (Halasz, 2007; Halasz et al. 2010).

## 7. Genetic diversity of apricot based on molecular markers

Apricot is a temperate and subtropical zones fruit. China, the Irano-Caucasian region (Turkey and Iran), Central Asia, Europe and North America are the main producer regions in the world. The Central Asia is the oldest and the primary genetic source of apricot group is the Central Asian accessions are self-incompatible; the Irano-Caucasian apricots which are mostly the cultivated ones are mostly self-incompatible, with large fruits and low chilling requirements. The European and the North American apricots are originated from Irano-Caucasia has relatively narrow genetic diversity and are self-compatible with large fruits (Mehlenbacher et al. 1991). For a long period, genetic diversity in apricot was studied with pomological, morphological and phenological characteristics (Guerriero & Watkins, 1984). DNA-based markers that have been used in the last decade clarify the relationship among the apricot accessions.

For breeding and commercialization of promising apricot cultivars, a precise characterization and discrimination of the cultivars are prerequisite. Different types of marker such as morphological, molecular, biochemical systems have been used for genetic analysis in horticultural plants. However, due to the effects of environmental factors, assessment of morphological and pomological traits may be ambiguous. Therefore, markers independent from the environment are necessary for reliable identification and discrimination of genotypes and cultivars. DNA markers are well known independent from environmental interactions and they show high level of polymorphism. Therefore, they are considered invaluable tools for determining genetic relationships/diversity. Various types of DNA markers are now available. Among them, RAPD developed by Williams et al. (1990) has been commonly used method in apricot to assess genetic variability and relationships among cultivars (Takeda et al. 1998; Zhebentyayeva et al. 2000; Hormaza, 2001; Mariniello et al. 2002; Ercisli et al. 2009). More recently, ISSR (Chenjing et al. 2005; Yilmaz, 2008), RFLP (De Vicente et al. 1998), AFLP (Hurtado et al. 2001, 2002; Hagen et al. 2002; Panaud et al. 2002; Geuna et al. 2003; Krichen et al. 2006; Yuan et al. 2007), SSR (Hormaza, 2002; Romero et al. 2003; Zhebentyayeva et al. 2003; Maghuly et al. 2005; He et al. 2006; Maghuly et al. 2006; Ali Khan et al. 2008) and SRAP (Uzun et al. 2010) techniques has also been used in apricot to characterize different cultivars belongs to diverse eco-geographical groups.

The diversity determined between apricot cultivars was probably due to crosses between wild and cultivated apricots and cultivars from different eco-geographic origin (Uzun et al. 2010). Microsatellite analyses suggested that European cultivars might have originated through hybridization among Irano-Caucasian genotypes and also most of the European cultivars have originated by hybridization with genotypes from the Irano-Caucasian group (Maghuly et al. 2005; Faust et al. 1998; Kostina, 1969). The heterozygosity of the apricot genotypes narrowed while apricot transfer from China to Europe. Pedryc et al. (2009) show that Middle European and Chinese apricot are distantly related.

Molecular markers have created new era in genetic diversity researches since early nineties. Restriction fragment length polymorphism (RFLP), and PCR based markers such as randomly amplified polymorphic DNA (RAPDs), sequence-related amplified polymorphism (SRAP), single nucleotide polymorphism (SNPs), micro-satellites or simple sequence repeats (SSRs) are mostly used marker systems in plants and also in apricot genetic diversity researches. Microsatellites among all is a very useful tool for apricot

diversity studies, and most promising to clearly genetic relation among the apricots and travel routes of apricots (Romero et al. 2003; Maghuly et al. 2005).

Amplified fragment length polymorphism (AFLP) molecular markers assessment for the genotyping of 118 commercial apricot accessions and some related apricot species (Geuna et al. 2003). The researchers clustered the apricots into four groups corresponding to their geographic distribution; (1) Mediterranean apricots, (2) Chinese apricots, (3) apricots of continental Europe and (4) Europe-North American apricots. Their data confirmed that the migration of apricot from the East to West. They also showed with molecular markers that *Prunus sibirica* and *Prunus mandshurica* are different from *Prunus armeniaca*, but they group together with Chinese accessions (Geuna et al. 2003). In another study Romero et al. (2003) studied apricots by using of SSR markers to determine the genetic relationships among genotypes from different eco-geographical groups. They observed that Western European and North American subgroups clustered together in agreement with their common origins from ancient European cultivars (Kostina, 1969; Bailey & Hough, 1975; Badanes et al. 1996). However their study placed Hungarian cultivars closer to the Central Asian group than to the other European cultivars.

Hayashi et al. (2008) studied Japanese apricot (*Prunus mume*) germplasm and reported that the genetic diversity and relationships among 127 Japanese apricot germplasms assessed by SSR markers. Their study supported the two hypotheses that Japanese apricot cultivated in Japan had been introduced from China and that fruiting cultivars had been selected from flower-ornamentals.

Turkish germplasm was studied by Yilmaz (2008) and Uzun et al. (2010) and genetic diversity and relationships among the accessions were determined using RAPD, ISSR, SRAP and SSR markers. The researchers reported the high genetic diversity in Turkish apricots. Four high chilling requiring cultivars originated from Eastern Turkey clustered apart from the rest. European, South African, North American and other Turkish cultivars were not clearly grouped regarding to their geographic districts. Therefore the researchers suggested that these cultivars, despite their different geographic origins, have similar genetic background.

## 8. References

- Acarsoy, N.; Evrenosoglu, Y.; Misirli, A.; Boztepe, O.; Yilmaz, K.U.; Gokalp, K.; Turkoglu, A. & Kokargul, R. (2011). Monilya'ya dayanikli yeni cesitlerin ıslahında farklı kombinasyonlarda meyve tutumu, tohum sayısı ve çimlenme oranı. Uluslar arası Katılımlı I. Ali Numan Kırac Tarım Kongresi Kitabı, Vol. 3, 2537-2543. (in Turkish)
- Akpınar, A.E.; Kocal, H.; Ergul, A.; Kazan, K.; Selli, M.E.; Bakir, M.; Aslantas, S.; Kaymak, S. & Saribas R. (2010). SSR-based molecular analysis of economically important Turkish apricot cultivars. *Genetics and Molecular Research* 9, 324-332.
- Ali Khan, M.; Maghuly, F.; Borroto-Fernandez, E.G.; Pedryc, A.; Katinger, H. & Laimer, M. (2008). Genetic diversity and population structure of apricot (*Prunus armeniaca* L.) from Northern Pakistan using Simple Sequence Repeats. *Silvae Genetica* 57(3), 157-164.

- Arakelyan, B. (1968). Excavations at Garni, 1949–50 in Contributions to the Archaeology of Armenia, (Henry Field, ed.), Cambridge, 1968, page 29.
- Arzani, K.; Nejatian, M.A. & Karimzadeh, G. (2005). Apricot (*Prunus armeniaca*) pollen morphological characterisation through scanning electron microscopy, using multivariate analysis. *New Zealand Journal of Crop and Horticultural Science* 33, 381–388.
- Asma, B. M. & Ozturk, K. (2005). Analysis of morphological, pomological and yield characteristics of some apricot germplasm in Turkey. *Genetic Resources and Crop Evolution* 52, 305–313.
- Asma, B.M. (2007). Malatya: The World's Capital of Apricot Culture", *Chronica Hort.* 47: 20–24.
- Asma, B.M. (2008). Determination of pollen viability, germination ratios and morphology of eight apricot genotypes. *African Journal of Biotechnology* 7, 4296–4273.
- Asma, B.M. (2011). Her yönüyle kayısı. Uyum Ajans, Ankara – Türkiye, p. 367. (in Turkish)
- Audergon, J.M.; Souty, M. & Breuils, L. (1990). Ame´lioration ge´ne´tique pour l'obtention d'abricots de qualite´. In 9\_Colloque sur les recherches fruitie`res. Avignon 4-5-6 de´cembre 1990. Ctifl-INRA, pp 217–228.
- Audergon, J.M.; Duffillol, J.M.; Gilles, F. & Signoret, V. (1993). Apricot selection in France: 9 new apricot cultivars for French growers. *Acta Hort.* 384, 237–243.
- Ayanoglu, H.; Kaska, N. & Yildiz, A. (1995). Akdeniz Bölgesi'nde erkenci kayısı çeşitlerinin adaptasyonu üzerinde araştırmalar. Türkiye II. Ulusal Bahçe Bitkileri Kongresi Kitabı, Vol. 1, 159–163. (in Turkish)
- Badanes, M.L.; Asins, M.J.; Carbonell, E.A. & Llacer, G. (1996). Genetic diversity in apricot, *Prunus armeniaca*, aimed at improving resistance to plum pox virus. *Plant. Breed.* 115, 133–139.
- Badanes, M.L.; Martinez-Calvo, J. & Llacer, G. (1998). Analysis of apricot germplasm from the European ecogeographical group. *Euphytica* 102, 93–99.
- Bailey, L.H. (1916). *Prunus*. In: The standard cyclopedia of horticulture, vol. V.P-R. Mount Pleasant Press, J. Horace McFarland Co., Harrisburg, PA, pp. 2822–2845.
- Bailey, L.H. & Hough, L.F. (1975). Apricots. In: Janick J, Moore JN (eds) *Advances in fruit breeding*. Purdue University Press, West Lafayette, Indiana, pp. 367–383.
- Baktir, I.; Ulger, S. & Yayıcı, Z.H. (1992). Yabancı orijinli bazı kayısı çeşitlerinin Antalya koşullarında adaptasyonu ve gelişmeleri üzerine bir araştırma. Türkiye I. Ulusal Bahçe Bitkileri Kongresi Kitabı, Vol. 1, 461–464. (in Turkish)
- Bassi, D., & Sansavini, S. (1988). Miglioramento genetico dell'albicocco: stata dele ricerche e prospettive. *Frutticoltura* 6, 11–22.
- Bassi, D. & Bartolozzi, F. (1993). Il miglioramento genetico dell'albicocco: obiettivi e strategie. *Rivista di Frutticoltura* 5, 41–50.
- Bassi, D.; Bellini, E.; Guerriero, R.; Monastra, F. & Pennone, F. (1995). Apricot Breeding in Italy. *Acta Hort.* 384, 47–54.
- Bassi, D. & Audergon, J.M. (2006). Apricot Breeding: Update and Perspectives. *Acta Hort.* 701, 279–294.



- Battistini, S. & Sansavini, S. (1991). Electrophoretic analysis of isozyme variability in apricot cultivars. *J. Genet. Breed.* 45, 117-122.
- Blanc, A.; Broquaire, J.M.; Chauffour, D.; Clauzel, G.; Duffillol, J.M.; Giard, A.; Gilles, F.; Moulon, B. & Audergon, J.M. (2006). Soledane, Florilege, Bergarouge ® Avirine, three new apricot cultivars for French Country. *Acta Hort.* 701, 395-398.
- Bortiri, E.; Oh, S.H.; Jiang, J.; Baggett, S.; Granger, A.; Weeks, C.; Buckingham, M.; Potter, D. & Parfitt, D.E. (2001). Phylogeny and systematics of *Prunus* (Rosaceae) as determined by sequence analysis of ITS and the chloroplast *trnL-trnF* spacer DNA. *Syst. Bot.* 26, 797-807.
- Bortiri, E.; Oh, S.H.; Gao, F.Y. & Potter, D. (2002). The phylogenetic utility of nucleotide sequence analysis of sorbitol 6-phosphate dehydrogenase in *Prunus* (Rosaceae). *Am. J. Bot.* 89, 1697-1708.
- Burgos, L.; Perez-Tornero, O.; Ballester, J. & Olmos, E. (1998). Detection and inheritance of stylar ribonucleases associated with incompatibility alleles in apricot. *Sex. Plant Reprod.* 11, 153-158.
- Buttner, R. (2001). *Armeniaca*. In: P. Hanelt (ed) Institute of Plant Genetics and Crop Plant Researches Mansfelds Encyclopedia of Agricultural and Horticultural Crops, pp 523-527.
- Cambra, M.; Capote, N.; Myrta, A. & Llácer, G. (2006). Plum pox virus and the estimated costs associated with sharka disease. *EPPO Bulletin* 36, 202-204.
- Chenjing, F.; Yuanhui, Z. & Xiuying, X. (2005). Genetic diversity revealed by ISSR marker in apricot. *Journal of Agricultural University of Hebei* 28(5), 52-55.
- Cociu, V.; Balan, V. & Oprea, M. (1991). The variability of field resistance against pathogenic agents *Monilia laxa* (Aderh. et Ruhl) honey and *Stignina carpophila* (LEV) M.B. Ellis and *Cytospora cincta* Sacc in some hybrids. *Acta Hort.* 293, 203-210.
- Crossa-Raynaud, P. (1960). Problems d'arboriculture fruitiere en Tunisie. Abricotiers. *Ann. L'Institut National de la Recherche Agronomique de Tunisie* 33, 39-63.
- Crossa-Raynaud, P. & Audergon, J.M. (1991). Some reflexions on apricot selections. *Acta Hort.* 293, 73-85.
- Davarynejad, G.H.; Szabó, Z.; Váci Felhösne, E.; Kun, Z. & Nyéki, J. (2005). Anther and pollen grain characteristics of apricot cultivars. *Acta Hort.* 384, 351-354.
- Demirtas, M.N.; Atay, S.; Gokalp, K.; Yilmaz, K.U.; Sahin, M.; Olmez, H.A.; Paydas Kargi, S.; Altindag, M. & Ercisli, S. (2010). Improvement of late blooming drying apricot varieties by crossbreeding. *Acta Hort.* 862, 219-223.
- De Nettancourt, D. (2001). Incompatibility and incongruity in wild and cultivated plants. 2nd ed. Springer-Verlag, New York.
- De Poerderlé, M. le Baron (1788). Manuel de l'Arboriste et du Forestier Beligues: Seconde Édition: Tome Premier (MDCCLXXXVIII). à Bruxelles: Emmanuel Flon. p. 682. Downloadable Google Books.
- De Vicente, M.C.; Truco, M.J.; Egea, J.; Burgos, L. & Arus, P. (1998). RFLP variability in apricot (*Prunus armeniaca* L.). *Plant Breed.* 117(2), 153-158.
- Dezhong, T.; Baoming, W.; Gaixiu, D. & Xiafung, F. (1995). Studies on the pollen morphology and ultrastructure of cultivated varieties of apricot (*Armeniaca vulgaris* Lam). *Acta Hort.* 403, 140-144.

- Draganescu, E. & Cociu, V. (1997). The modernizing of the apricot assortment of cultivars in Banat Area of Romania. *Acta Hort.* 488(1), 149-151.
- Durie, B. (1988). Commercial characteristics of some apricot varieties in Vojvodina. *Hort. Abstr.* 61(4), 2615.
- Egea, J.; Garcia, J.E.; Egea, L. & Berenguer, T. (1993). Productive behaviour of apricot varieties in a warm winter area. *Acta Hort.* 384, 129-133.
- Egea, J. & Burgos, L. (1996). Detecting cross-incompatibility of three North American apricot cultivars and establishing the first incompatibility group in apricot. *J. Amer. Soc. Hort. Sci.* 121, 1002-1005.
- Entani, T.; Iwano, M.; Shiba, H.; Che, S.F.; Isogai, A. & Takayama, S. (2003). Comparative analysis of the self-incompatibility (S-) locus region of *Prunus mume*: Identification of a pollen-expressed *F-box* gene with allelic-diversity. *Genes. Cells* 8, 203-213.
- Ercisli, S.; Agar, G.; Yildirim, N.; Esitken, A. & Orhan, E. (2009). Identification of apricot cultivars in Turkey (*Prunus armeniaca* L.) using RAPD markers. *Romanian Biotechnological Letters* 14, 4582-4588.
- FAOSTAT (2011). FAO web page, [www.fao.org](http://www.fao.org)
- Faust, M.; Suranyi, D. & Nyujto, F. (1998). Origin and Dissemination of Apricot. *Horticultural Reviews* 22, 248-249.
- Felföldi, J.; Firtha, F.; Herman, R. & Pedryc, A. (2009). Characterisation of morphological properties of apricot stones by image processing. *Bornimer Agrartechnische Berichte, Helf* 69, 162-169.
- Geuna, F.; Toschi, M. & Bassi, D. (2003). The use of AFLP markers for cultivar identification in apricot. *Plant. Breed.* 122, 526-531.
- Guerriero, R. & Watkins, R. (1984). Revised descriptor list for apricot (*Prunus armeniaca*). IBPGR Secretariat, Rome, CEC Secretariat, Brussels.
- Guerrieri, F.; Audergon, J.M.; Albagnac, G. & Reich, M. (2001). Soluble sugars and carboxylic acids in ripe apricot fruit as parameters for distinguishing different cultivars. *Euphytica* 117, 183-189.
- Guerriero, R.; Monteleone, P. & Iacona, C. (2006). Apricot Breeding in Pisa: Some New Selections for Italian Growers. *Acta Hort.* 701, 341-346.
- Gulcan, R.; Misirli, A. & Demir, T. (1994). Hacıhaliloğlu Kayısı Çeşidinin Melezleme Yoluyla Monilya (*Sclerotinia* (*Monilinia*) *laxa* Aderh et., Ruhl) Hastalığına Dayanıklılık Islahı Üzerinde Bir Araştırma - TÜBİTAK Proje No. TOAG-806. (in Turkish)
- Hagen, L.; Khadari, B.; Lambert, P. & Audergon, J.M. (2002). Genetic diversity in apricot revealed by AFLP markers: species and cultivar comparisons. *Theor. Appl. Genet.* 105(2-3), 298-305.
- Halasz, J.; Hegedus, A.; Herman, R.; Stefanovits-Banyai, E. & Pedryc, A. (2005). New self-incompatibility alleles in apricot (*Prunus armeniaca* L.) revealed by stylar ribonuclease assay and S-PCR analysis. *Euphytica* 145, 57-66.
- Halasz, J. (2007). Molecular background of the S-locus controlled self-incompatibility in apricot. PhD Diss., Corvinus University of Budapest, Budapest – Hungary.
- Halasz, J.; Pedryc, A. & Hegedus, A. (2007). Origin and dissemination of the pollen-part mutated *Sc*-haplotype that confers self-compatibility in apricot (*Prunus armeniaca*). *New Phytol.* 176, 793-803.

- Halasz, J.; Pedryc, A.; Ercisli, S.; Yilmaz, K.U. & Hegedus, A. (2010). S-genotyping supports the genetic relationships between Turkish and Hungarian apricot germplasm. *J. Amer. Soc. Hort. Sci.* 135(5), 410-417.
- Harsanyi, J. (1991). Evaluation of apricot varieties at a plain site exposed to frost. *Acta Hort.* 293, 217-220.
- Hayashi, K.; Shimazu, K.; Yaegaki, H.; Yamaguchi, M.; Iketani, H. & Yamamoto, T. (2008). Genetic diversity in fruiting and flower-ornamental Japanese apricot (*Prunus mume*) germplasms assessed by SSR markers. *Breeding Science* 58, 401-410.
- He, T.M.; Chen, X.S.; Gao, J.S.; Zhang, D.H.; Xu, L. & Wu, Y. (2006). Using SSR markers to study population genetic structure of cultivated apricots native to Xinjiang. *Acta Hort. Sinica* 33, 809-812. (in Chinese with an English abstract)
- Hofstee, M.E.; Malona, M. & Howard, C. (1997). Apricot breeding in New Zealand. *Acta Hort.* 488(1), 171-172.
- Hormaza, J.I. (2002). Molecular characterization and similarity relationships among apricot (*Prunus armeniaca* L.) genotypes using simple sequence repeats. *Theor. Appl. Genet.* 104(2-3), 321-328.
- Horiuchi, S.; Yoshida, M.; Kariya, H.; Nakamura, T.; Hasebe, H.; Suzaki, T. & Sakitani, T. (1996). *Nihonnoume Sekainoume*. Yokendo.
- Hou, H.Y. (1983). Vegetation of China with reference to its geographical distribution. *Ann. Missouri Bot. Gard.* 70, 509-548.
- Hurtado, M.A.; Badenes, M.L.; Llacer, G.; Westman, A.; Beck, E. & Abbott, G.A. (2001). Contribution to apricot genetic analysis with RFLP, RAPD and AFLP markers. *Acta Hort.* 546, 417-420.
- Hurtado, M.A.; Westman, A.; Beck, E.; Abbott, G.A.; Llacer, G. & Badenes, M.L. (2002). Genetic diversity in apricot cultivars based on AFLP markers. *Euphytica* 127, 297-301.
- Huxley, A. (1992). *New RHS Dictionary of Gardening* 1: 203-205. Macmillan ISBN 0-333-47494-5.
- Karp, A.; Seberg, O. & Buiatti, M. (1996). Molecular techniques in the assessment of botanical diversity. *Ann. Bot.* 78, 143-149.
- Kaska, N.; Yildiz, A.; Ayanoglu, H.; Saglam, M. & Gungor, M.K. (1993). Apricot adaptation studies in the Mediterranean coastal region in Turkey. *Acta Hort.* 384, 67-71.
- Kegler, H.; Fuchs, E.; Grüntzig, M. & Schwarz, S. (1998). Some results of 50 years of research on the resistance to plum pox virus. *Acta Virol.* 42, 200-215.
- Kostina, K.F. (1969). The use of varietal resources of apricots for breeding. *Trud. Nikit. Bot. Sad.* 40, 45-63. (in Russian)
- Kostina, K.F. (1970). Self-fertility studies in apricot. *Trud. Nikit. Bot. Sad.* 45, 7-17. (in Russian)
- Krichen, L.; Trifi-Farah, N. & Marrakchi, M. (2006). Variability, organisation and identification of Tunisian apricot (*Prunus armeniaca* L.) cultivars using AFLP markers. *Acta Hort.* 717, 251-254.
- Layne, R.E.C.; Bailey, C.H. & Hough, L.F. (1996). Apricots. J. Janick and J.M. Moore (Eds.) In: *Fruit Breeding, Vol 1: Tree and tropical fruits*, pp. 79-111, John Wiley and Sons, New York.

- Ledbetter, C.A. & Pettersen, S. J. (2004). Utilization of Pakistani apricot (*Prunus armeniaca*) germplasm for improving brix levels in California adapted apricots. *Plant Genetic Resources Newsletter* 140, 14-22.
- Ledbetter, C.A. (2008). Apricots: Hancock, J.F. (eds), Temperate Fruit Crop Breeding: Germplasm to genomics, Chapter 2, pp. 39-82. Springer Science-Business Media B.V.,
- Lingdi, L. & Bartholomew, B. (2003). *Armeniaca*. In: Wu, C.Y., Raven, P.H. (eds.) *Flora of China*, vol 9 (*Pittosporaceae* through *Connaraceae*). Science Press, Beijing, and Missouri Botanical Garden Press, St. Louis. pp 396-401.
- Lopez-Moya, J.; Fernandez-Fernandez, M.; Cambra, M. & Garcia, J. (2000). Biotechnological aspects of plum pox virus. *J. Biotechnol.* 76, 121-136.
- Loudon, J.C. (1838). *Arboretum Et Fruticetum Britannicum*. Vol. II. London: Longman, Orme, Brown, Green and Longmans. pp.681-684. The genus is given as *Armeniaca*. Downloadable at Google Books.
- Maghuly, F.; Borroto Fernandez, E.; Zelger, R.; Marschall, K.; Katinger, H. & Laimer, M. (2006). Genetic differentiation of apricot (*Prunus armeniaca*) cultivars with SSR markers. *Europ. Journal of Horticultural Science* 71, 129-134.
- Maghuly, F.; Borroto Fernandez, E.; Ruthner, S.; Pedryc, A. & Laimer, M. (2005). Microsatellite variability in apricot (*Prunus armeniaca*) reflects their geographical origin and breeding history. *Tree Genetics & Genomes* 1, 151-165.
- Malik, S.K.; Chaudhury, R.; Dhariwal, O.P. & Mir, S. (2010). Genetic diversity and traditional uses of wild apricot (*Prunus armeniaca* L.) in high-altitude north-western Himalayas of India. *Plant Genetic Resources: Characterization and Utilization* 8, 249-257.
- Marinello, L.; Sommella, M.G. & Sorrentina, A. (2002). Identification of *Prunus armeniaca* cultivars by RAPD and SCAR markers. *Biotechnology Letters* 24, 749-755.
- Martinez-Gomez, P.; Dicenta, F. & Audergon, J.M. (2000). Behaviour of apricot (*Prunus armeniaca* L.) cultivars in the presence of Sharka (*Plum pox potyvirus*): a review. *Agronomie* 20, 407-422.
- McClure, B.A.; Haring, V.; Ebert, P.R.; Anderson, M.A.; Simpson, R.J.; Sakiyama, F. & Clarke, A.E. (1989). Style self-incompatibility gene products of *Nicotiana glauca* are ribonucleases. *Nature* 342, 955-957.
- Mega, K.; Tomita, E.; Kitamura, S.; Saito, S. & Mizukami, S. (1988). Ume. In: Aoba et al. (Eds.) *The Grand Dictionary of Horticulture*, Shogakukan, Tokyo, pp. 289-300.
- Mehlenbacher, S.A.; Cociu, V. & Hough, L.F. (1991). Apricots (*Prunus*). In: Moore J. N., Ballington J. R. (eds) *Genetic Resources of Temperate Fruit and Nut Crops*. *Acta Hort.* 290, 63-109.
- Milosevic, T.; Milosevic, N.; Glisic, I. & Krska, B. (2010). Characteristics of promising apricot (*Prunus armeniaca* L.) genetic resources in Central Serbia based on blossoming period and fruit quality. *Hort. Sci. (Prague)* 37(2), 46-55.
- Nicotra, A.; Conte, L.; Moser, L.; Fantechi, P.; Corazza, L.; Vitale, S. & Magnotta, A. (2006). Breeding programme for *Monilinia laxa* (Aderh et., Ruhl.) resistance on apricot. *Acta Hort.* 701, 307-311.
- Occorso, G. (1977). The apricot in Western Sicily, description of interesting very early cultivar. *Hort. Abstr.* 51(10), 7656.



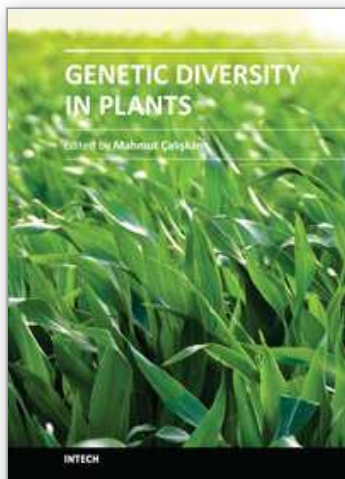
- OECD (2002) Consensus document on the biology of *Prunus* sp. (stone fruits): series on harmonization of regulatory oversights in biotechnology nr. 24. <http://www.oilis.oecd.org/oilis/2002doc.nsf/LinkTo/env-jm-mono>
- Ogasanovic, D.; Plazinic, R.M. & Papic, U.M. (1991). Results from study of some early apricot cultivars on various interstock. *Acta Hort.* 293, 383-389.
- Ozvardar, S.; Onal, K. & Baldiran, E. (1991). Ege Bölgesi'ne uygun kayısı çeşitlerinin seçimi. *Anadolu Ege Tarımsal Araştırma Enstitüsü Dergisi* 2, 36-52. (in Turkish)
- Panaud, O.; Chaib, A. & Sarr, A. (2002). Dynamic conservation of apricot *Prunus armeniaca* in Saharian oases: use of AFLP markers to assess genetic diversity in traditional orchards. *Euphytica* 128, 301-305.
- Papanikolaou-Paulopoulou, X. & Poulis, J. (1997). Evaluation of fourteen (14) different apricot varieties at the Agricultural Research Station of Rhodes. *Acta Hort.* 488(1), 185-189.
- Parolari, G.; Virgili, R. & Bolzoni, L. (1992). Analysis of sensory and instrumental data on apricot purees with pattern recognition techniques. *Analitica Chimica Acta* 259, 257-265.
- Paydas, S.; Kaska, N. & Durgac, C. (1995). Yerli ve yabancı bazı kayısı çeşitlerinin Pozantı ekolojik koşullarındaki performansları. Türkiye II. Bahçe Bitkileri Kongresi Kitabı, Vol. 1, 169-173. (in Turkish)
- Pedryc, A.; Ruthner, S.; Herman, R.; Krska, B.; Hegedus, A. & Halasz, J. (2009). Genetic diversity of apricot revealed by a set of SSR markers from linkage group G1. *Sci. Hort.* 121, 19-26.
- Perez-Gonzales, S. (1992). Associations among morphological and phenological characters representing apricot germplasm in Central Mexico. *J. Amer. Soc. Hort. Sci.* 117, 486-490.
- Rao, R.; Bencivenni, M.; Basile, B. & Forlani, M. (2008). Molecular characterization of the apricot cultivars of protected geographical indication (PGI) "Albicocca Vesuviana". XIV. International Symposium on Apricot Breeding and Culture, 16-20 June 2008, Matera (Italy), abstract books.
- Rehder, A. (1940). Manual of cultivated trees and shrubs hardy in North America, exclusive of the subtropical and warmer temperate regions, 2nd revised and enlarged edition. Macmillan, New York.
- Rodrigo, J.; Herrero, M. & Hormaza, J.I. (2006). Morphological and physiological parameters related to flower quality in apricot. *Acta Hort.* 717, 89-90.
- Romero, C.; Pedryc, A.; Munoz, V.; Llacer, G. & Badenes, M.L. (2003). Genetic diversity of different apricot geographical groups determined by SSR markers. *Genome* 46, 244-252.
- Romero, C.; Vilanova, S.; Burgos, L.; Martinez-Calvo, J.; Vicente, M.; Llacer, G. & Badenes, M.L. (2004). Analysis of the S-locus structure in *Prunus armeniaca* L.: Identification of S-haplotype specific S-RNase and F-box genes. *Plant Mol. Biol.* 56, 145-157.
- Romero, C.; Llacer, G.; Badenes, M.L. & Pedryc, A. (2006). Relationship among apricot cultivars from Hungary and a South European pool determined by SSR markers. *Acta Hort.* 701(1), 233-240.
- Rostova, N.S. & Sokolova, E.A. (1992). Variability of anatomical and morphological leaf characters in apricot (*Armeniaca* Scop.) species and varieties. *Bull. Appl. Bot. Genet. Plant Breed.* 146, 74-86.

- Ruiz, D. & Egea, J. (2008). Phenotypic diversity and relationships of fruit quality traits in apricot (*Prunus armeniaca* L.) germplasm. *Euphytica* 163, 143-158.
- Sanchez-Pe´rez, R.; Ruiz, D.; Dicenta, F.; Egea, J. & Martinez- Gomez, P. (2005). Application of simple sequence repeat (SSR) markers in apricot breeding: Molecular characterisation, protection and genetic relationships. *Scientia* 103, 305-315.
- Souty, M.; Audergon, J.M. & Chambroy, Y. (1990). Abricot: les crite`res de qualite´. *L'Arboriculture fruitie`re* 430, 16-24.
- Suranyi, D.; 1999. Apricot culture in Hungary: Past and present. *Acta Hort.* 488, 205-210.
- Szabo, Z. & Nyeki, J. (1991). Blossoming, fructification and combination of apricot varieties. *Acta Hort.* 293, 295-302.
- Takeda, T.; Shimada, T.; Nomura, K.; Ozaki, T.; Haji,T.; Yamaguchi, M. & Yoshida, M. (1998). Classification of apricot varieties by RAPD analysis. *Journal of the Japanese Society for Horticultural Science* 67, 21-27.
- TurkStat (2010). Turkish Statistical Institute, [www.turkstat.gov.tr](http://www.turkstat.gov.tr)
- Vargas, F.J., & Romero, M.A. (2001). Blooming time in almond progenies. *Options Me´diterran* 56, 29-34.
- Vavilov, N.I. (1951). Phytogeographic basis of plant breeding. The origin, variation, immunity and breeding of cultivated plants. K.S. Chester (translated). *Chron. Bot.* 13, 13-54.
- Vilanova, S.; Romero, C.; Abbott, A.G.; Llacer, G. & Badanes, M.L. (2003). An apricot (*Prunus armeniaca* L.) F<sub>2</sub> progeny linkage map based on SSR and AFLP markers, mapping Plum pox virus resistance and self-incompatibility traits. *Theor. Appl. Genet.* 107(2), 239-247.
- Viti, R.; Bartolini, S. & Minnocci, A. (2000). Morphological structure of the stigma and style of several genotypes of *Prunus armeniaca* L. *Plant Biosystems* 134, 45-51.
- Williams, J.G.K.; Kubelik, A.R.; Livak, K.J.; Rafalski, J.A. & Tingey, S.V. (1990). DNA polymorphism amplified by arbitrary primers are useful as genetic markers. *Nucleic Acids Res.* 18, 6531-6535.
- Yilmaz, K.U. (2002). Studies on table apricot growing for export in Kahramanmaras. University of Kahramanmaras Sutcu Imam, Institute of Natural and Applied Science, Department of Horticulture, MSc Thesis. (in Turkish with English abstract)
- Yilmaz, K.U. (2008). Phenological, morphological and pomological characteristics of some local apricot genotypes and determination of their genetic relationships and self-incompatibility by molecular markers. Department of Horticulture Institute of Basic and Applied Sciences University of Cukurova, Adana-Turkey, PhD Thesis, (in Turkish with an English abstract).
- Yilmaz, K.U. & Paydas-Kargi, S. (2010). A new morphological trait for apricot characteristics. *Acta Hort.* 862, 83-84.
- Yuan, Z.; Chen, X.; He, T.; Feng, J.; Feng, T. & Zhang, C. (2007). Population genetic structure in apricot (*Prunus armeniaca* L.) cultivars revealed by fluorescen-AFLP markers in Southern Xinjiang, China. *J. of Genetics and Genomes* 37(4), 1037-1047.
- Zhebentyayeva, T.N. & Sivolap, Y.M. (2000). Genetic diversity of apricot determined by isozyme and RAPD analyses. *Acta Hort.* 538, 525-529.
- Zhebentyayeva, T.N.; Reighard, G.L.; Gorina, V.M. & Abbott, A.G. (2003). Microsatellite (SSR) analysis for assessment of genetic variability in apricot. *Theor. Appl. Genet.* 106, 435-444.

- Zhebentyayeva, T., Reighard, G., Lalli, D., Gorina, V., Krška, B. & Abbott, A.G. (2008). Origin of resistance to plum pox virus in apricot: what new AFLP and targeted SSR data analyses tell. *Tree Genet. Genomes* 4, 403–417.
- Zohary, D. & Spiegel Roy, P. (1975). Beginning of fruit growing in the Old World. *Science* 187, 319–327.

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Genetic diversity is of fundamental importance in the continuity of a species as it provides the necessary adaptation to the prevailing biotic and abiotic environmental conditions, and enables change in the genetic composition to cope with changes in the environment. Genetic Diversity in Plants presents chapters revealing the magnitude of genetic variation existing in plant populations. The increasing availability of PCR-based molecular markers allows the detailed analyses and evaluation of genetic diversity in plants and also, the detection of genes influencing economically important traits. The purpose of the book is to provide a glimpse into the dynamic process of genetic variation by presenting the thoughts of scientists who are engaged in the generation of new ideas and techniques employed for the assessment of genetic diversity, often from very different perspectives. The book should prove useful to students, researchers, and experts in the area of conservation biology, genetic diversity, and molecular biology.

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