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Breeding of Self-Compatible and Late Flowering Cultivars in Almond

İzzet AÇAR[1*] Salih KAFKAS[2] Bekir Erol AK[1]
[1] Department of Horticulture, Faculty of Agriculture, Harran University, Şanlıurfa, TURKEY
[2] Department of Horticulture, Faculty of Agriculture, Çukurova University, Adana, TURKEY

***Corresponding Author**
E-mail:izzetacar@harran.edu.tr

Abstract
Almond is one of the important fruit species in Turkey, and it is being imported. Domestic almond cultivars do not take any attention of the market, as a result nurserymen prefer new foreign cultivars. In 2009, through our project, supported by TUBITAK, "Self-compatible and late flowering almond breeding by crossing" an Almond Breeding Program has been started. In the first part of the breeding program, in 2009 self-compatible foreign almond cultivars Lauranne, Guara and Moncayo were crossed with the local cultivars Gulcan 1, Gulcan 2, Akbadem and Nurlu and F1 plants containing self-compatible allele (S_f) were determined by PCR method, and these plants were planted in Pistachio Research Institute in 2011. In addition, the F1 individuals obtained from the 'Gulcan 2' x 'Penta' and 'Gulcan 2' x 'A2-198' crossing made in 2011 were also planted in F1 plot in 2012. Thus, for the first time in our country, an almond population has been created, which is candidate for self-compatible and late flowering. Total 1.870 F1 individuals in this population have been used as material of the project.
Seventeen F1 individuals were selected, and transported to the Selection II plots both in Şanlıurfa and Gaziantep.

Keywords: Almond, Breeding, Late Flowering, Self-Compatibility

INTRODUCTION

Turkey has considerable potential in terms of almond production. However, the great parts of almond trees grown in Turkey are seedlings. For this reason, local almond fruits in the markets have contain double kernel, large and small fruits, dark and light colored kernel, and mixtures of bitter and sweet almonds. Thus, in recent years, our country has been importing almonds [1].

According to average almond production during last 3 years; Turkey's almond production is 79.410 tons, and 6th in the world [2]. Mediterranean, Southeast Anatolia and Aegean regions have a potential for modern almond growing in Turkey. The Southeast Anatolian Project (GAP) is the largest irrigation and development project of Turkey covering about two million ha cultivated land. In recent years, modern almond orchards with foreign cultivars are being established in the GAP region. The promising results were obtained from the almond cultivar adaptation studies carried out in the GAP region [3], [4] and [5].

Spring frosts are restrictive factor for almond cultivation, and for this reason, late flowering is very important characteristic for almond cultivars. On the other hand, Turkish almond cultivars are in the hard-shell almond class, and self-incompatible. Domestic almond cultivars do not attract the interest of the market, and nursery production is done with foreign almond cultivars in Turkey.

The self-compatible almond cultivar would be desirable in the orchards with lower costs in crop management and higher yields. As there are no pollination and fertilization problems, more crops can be obtained from self-compatible cultivars. For this reason, self-compatibility is one of the main objectives in almond breeding programs [6], [7], [8], [9], [10] and [11].

When the self-compatible almond cultivars are used as parent in the crossing, the self-fertility can be passed on to the offsprings.

The new self-compatible foreign almond cultivars were developed by crossing [12], [7], [10], [13], [14], [15], [16] and [17].

There are no self-compatible local almond cultivars in Turkey, and almost all new almond orchards have been established with foreign cultivars. The spring frost has also caused to product loss. Therefore, both self-compatible and late flowering new almond cultivars are targeted in our breeding program. An "Almond Breeding Program" was initiated in 2009 with a project titled "Self-Compatible and Late Flowering Almond Breeding by Crossing" supported by TUBITAK [18]. In 2009, self-compatible 'Lauranne', 'Guara' and 'Moncayo' crossed with 'Gülcan 1', 'Gülcan 2', 'Akbadem' and 'Nurlu. F1 plants containing self-compatible allele (Sf) were identified by the S allele PCR method. In addition, 'Gülcan 2 × Penta' and 'Gülcan 2 × A2-198' crossings made in 2011. Pollen of these 2 genotypes were obtained from CEBAS-CSIC Institute in Murcia, Spain. These individuals were planted at the Pistachio Research Institute in 2011 with 2 m x 1 m distances. Finally, a self-compatible and late flowering almond population has been created for the first time in Turkey [19].

The aim of our Almond Breeding Program is to develop self-compatible and late-flowering new almond cultivars that have international characteristics. We aimed to achieve late flowering, self-compatibility, high production capacity, easy tree training and pruning, tolerance to diseases and, nut and kernel quality.

MATERIALS AND METHODS

Total 1.870 F1 plants containing S_f allele have been used as plant material in our breeding program. Selection studies were carried out on plant, nut and kernel characteristics.

Tree Characteristics
a) Age of start bearing
b) Full flowering time (compared with Lauranne)
c) Flower density
d) Yield efficiency
e) Ripening time
f) Tree vigour
g) Tree habit
h) Easy tree training and pruning
i) Autogamy

Nut and Kernel Characteristics
a) Nut weight
b) Shell hardness
c) Kernel weight
d) Shelling percentage
e) Double kernel
g) Shriveling of kernel
h) Kernel colour intensity
i) Kernel taste

Negative selection was made in F1 individual plot. Individuals with negative characteristics were marked and removed from the plot.

Identification of S alleles of domestic parents

The S allelles of 'Akbadem', 'Gülcan 1', 'Gülcan 2' and 'Nurlu' varieties used as parents in the breeding program were identified.

Establishment of Selection II Orchards

Selection II orchards were established in Şanlıurfa and Gaziantep on February 2017.

RESULTS AND DISCUSSION

The offsprings transferred to Selection II stage were coded in alphabetic letters coded. Tree, nut and kernel characteristics of offsrings were determined in the study.

Tree Characteristics

Tree characteristics were observed for age of start bearing, full flowering time (compared with Lauranne), flower density, yield efficiency, ripening time, tree vigour, tree habit, easy tree training and pruning, and autogamy (see Table 1).

All selected F_1 individuals and Lauranne cutivar started fruit bearing 4 years after planting, except for A individual. Yield per tree ranged from 435 g to 3.070 g. While the flowering of the 11 hybrid individuals was after Lauranne, the flowering of 6 individuals was before Lauranne. Flower density of offsprings ranged from sparse to extremely dense. Early ripening is very important characteristic for almond cultivars. These were between 3 and 25 August, while 8 August for Lauranne. Tree vigour was weak in 1 individual, intermediate in 9 individuals and strong in 7 individuals, while intermediate in Lauranne. Tree habit was semi-upright in 3 offspring and Lauranne, and upright in the rest offsprings. Tree training and pruning was difficult only in 1 individual, and autogamy percent ranged from 4% to 67%.

Table 1. Tree Characteristics of F1 Individuals transferred to Selection II Orchards

F_1 Individuals	Age of Start Bearing	Yield per Tree g	Flowering Time*	Flower Density	Ripening Time	Tree Vigour	Tree Habit	Easy Tree Training and Pruning	Autogamy %
A	3	2.650	-	Dense	12 August	Strong	Upright	Intermediate	4
B	4	2.800	-	Intermediate	20 August	Strong	Upright	Easy	34
C	4	2.720	+	Extremely dense	5 August	Intermediate	Semi-upright	Easy	49
D	4	835	++	Extremely dense	11 August	Strong	Upright	Easy	31
E	4	980	+	Extremely dense	12 August	Strong	Upright	Easy	45
F	4	435	++	Dense	17 August	Intermediate	Upright	Very Easy	49
G	4	815	++	Intermediate	28 August	Intermediate	Semi-upright	Easy	58
H	4	920	- - -	Intermediate	21 August	Weak	Upright	Very Easy	35
I	4	2.545	++	Intermediate	12 August	Strong	Semi-upright	Easy	67
J	4	540	- - -	Sparse	25 August	Intermediate	Upright	Easy	45
K	4	650	- - - -	Intermediate	12 August	Strong	Upright	Intermediate	41
L	4	2.500	+	Extremely dense	3 August	Strong	Upright	Intermediate	5
M	4	2.660	++	Dense	5 August	Intermediate	Upright	Intermediate	17
N	4	3.070	-	Dense	9 August	Intermediate	Upright	Intermediate	48
O	4	565	++	Sparse	15 August	Intermediate	Upright	Difficult	41
P	4	1.445	++	Intermediate	13 August	Intermediate	Upright	Intermediate	55
R	4	625	+	Sparse	14 August	Intermediate	Upright	Intermediate	24
Lauranne	4	1.860	0	Extremely dense	8 August	Intermediate	Semi-upright	Very Easy	34

* -: day before Lauranne cultivar, +:day after Lauranne cultivar

Nut and Kernel Characteristics

Nut and kernel characteristics were evaluated on nut weight, shell hardness, kernel weight, shelling percentage, double kernel, shriveling of kernel, kernel colour intensity and kernel taste (see Table 2).

Nut weight of offsprings ranged between 2.03 and 6.74 g; shell hardness was generally intermediate, but very soft in an individual and extremely hard in 2 individuals. Kernel weight ranged from 0.55 g to 1.25 g, and shelling percentage was between 19.80% and 31.23%, while 28.12% in Lauranne. Double kernel rate of offsprings ranged from 0% to 27.5%. Shriveling of kernel was slightly wrinkled in 2 offsprings, wrinkled in 2 offsprings and Lauranne, intermediate in 13 offsprings. Kernel colour intensity ranged from extremely light to dark. Kernel taste of 15 individuals was determined as sweet except for 2 individuals.

Table 2. Nut and Kernel Characteristics of F1 Individuals transferred to Selection II Orchards

F_1 Individuals	Nut Weight g	Shell Hardness	Kernel Weight g	Shelling Percentage %	Double Kernel %	Shriveling of Kernel	Kernel Colour Intensity	Kernel Taste
A	2.03	Intermediate	0.55	27.09	1.25	Intermediate	Intermediate	Sweet
B	2.30	Intermediate	0.70	30.43	3.75	Wrinkled	Dark	Sweet
C	2.15	Intermediate	0.59	27.25	0	Intermediate	Intermediate	Sweet
D	3.03	Intermediate	0.74	24.51	1.25	Intermediate	Light	Sweet
E	3.01	Intermediate	0.94	31.23	1.25	Intermediate	Light	Sweet
F	2.05	Very Soft	0.63	30.81	0	Intermediate	Intermediate	Sweet
G	3.99	Hard	0.87	21.81	0	Slightly wrinkled	Intermediate	Intermediate
H	3.40	Hard	0.76	22.27	6.25	Intermediate	Light	Sweet
I	2.11	Intermediate	0.62	29.46	0	Intermediate	Dark	Intermediate
J	6.34	Extremely hard	1.25	19.80	8.75	Intermediate	Light	Sweet
K	6.74	Extremely hard	0.95	25.67	27.5	Wrinkled	Extremely light	Sweet
L	3.08	Intermediate	0.80	26.06	3.75	Intermediate	Light	Sweet
M	3.58	Intermediate	0.88	24.61	3.75	Intermediate	Intermediate	Sweet
N	3.60	Hard	0.90	25.28	17.5	Slightly wrinkled	Intermediate	Sweet
O	2.74	Intermediate	0.78	28.25	0	Intermediate	Dark	Sweet
P	2.68	Intermediate	0.74	27.39	1.25	Intermediate	Light	Sweet
R	2.62	Soft	0.73	28.02	1.25	Intermediate	Light	Sweet
Lauranne	2.17	Soft	0.61	28.12	1.25	Wrinkled	Intermediate	Sweet

Identification of S alleles of domestic parents

The S allelles of 'Akbadem', 'Gülcan 1', 'Gülcan 2' and 'Nurlu' varieties used as parents in the breeding program were identified.

Nurlu : $S_{10}S_{51}$
Akbadem : $S_{10\text{-}1}S_{23}$
Gülcan 1 : $S_{10}S_{24}$
Gülcan 2 : $S_{53}S_{54}$

It was determined that the alleles determined in 'Gülcan 2' were new alleles for almond and the obtained sequences were loaded on the *National Center for Biotechnology Information* (NCBI) gene bank.

https://www.ncbi.nlm.nih.gov/nuccore/1028340896 (S-53 allele)
https://www.ncbi.nlm.nih.gov/nuccore/1028340898 (S-54 allele)

Establishment of Selection II Orchards

Selection II (adaptation) orchards were established with 17 F_1 self-fertile individuals and 3 control cultivars (Ferragnes, Guara and Lauranne) grafted onto GF-677 clonal rootstock, both at Harran University, Faculty of Agriculture in Şanlıurfa, and at the Pistachio Research Institute in Gaziantep in February 2017.

CONCLUSION

The Almond Breeding Program will continue to work on the breeding and registration of new almond varieties with the first native self-fertile almond genotypes carried to Selection II orchards. The aim of this program is to develop self-fertile and late flowering new almond cultivars with international characteristics.

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