

International Journal of Fruit Science

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/wsfr20

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To cite this article: Mehmet Yaman & Aydın Uzun (2020) Evaluation of Superior Hybrid Individuals with Intra and Interspecific Hybridization Breeding in Apricot, International Journal of Fruit Science, 20:sup3, S2045-S2055, DOI: 10.1080/15538362.2020.1852151

To link to this article: https://doi.org/10.1080/15538362.2020.1852151

Published online: 30 Nov 2020.

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INTERNATIONAL JOURNAL OF FRUIT SCIENCE
2020, VOL. 20, NO. S3, S2045–S2055
https://doi.org/10.1080/15538362.2020.1852151

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Evaluation of Superior Hybrid Individuals with Intra and Interspecific Hybridization Breeding in Apricot

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ABSTRACT

Turkey has quite a rich genetic diversity in various fruit and plant species. **One of them is species in *the Prunus* genus. In addition, Turkey is the greatest or significant producer of many stone, nut and some fruit species**. This study was conducted to determine the effects of intra-species hybridizations of some apricot (*Prunus armeniaca* L.) cultivars and inter-species hybridization of apricot cultivars with paternal parent plum (*Prunus **salicina*** L.) cultivars on fruit set and **pomological properties** of apricots. In both years of experiments, differences were observed in fruit set ratios of intra and inter-species hybrid combinations based on paternal parent cultivars. Among the apricot × plum inter-species hybrid combinations, the Black Amber plum cultivar was found to be prominent for the investigated parameters. Among the apricot × apricot intra-species hybrid combinations, Palstein group hybrids yielded greater values for the investigated parameters. Present findings may guide further researches to be conducted on intra and inter-species hybridizations of apricots and plums.

KEYWORDS

hybridization; *Prunus armeniaca*; *Prunus salicina*

Introduction

Turkey has diverse climates ranging from sub-tropical to terrestrial, thus allows both natural growth and economic culture of various plant species (Pınar et al., 2019). **Turkey has a great genetic diversity in *Prunus species*. Turkey is among the world's most important manufacturers of *Prunus* species such as stone, nut and some fruit species** (Uzun et al., 2018).

Apricot (*Prunus armeniaca* L.) is a stone-fruit (Batnini et al., 2019). **Apricot fruit is among the preferred fruits in human health and nutrition thanks to its biochemical compounds and rich nutritional contents** (Gündoğdu, 2019)**. Thus, world annual apricot production was about 4 million tons in 2017 and Turkey with an annual production of 985.000 tons is the leading apricot (*Prunus armeniaca* L.) producer of the world (FAO, 2017**). Although Turkey is not among the motherlands, apricot (*Prunus armeniaca* L.) has well adapted to regional conditions nationwide. Turkish growers experience various problems about fruit set and yield of apricot (*Prunus armeniaca* L.) orchards.

Self-incompatibility is a widespread mechanism in the Rosacea family including pears (*Pyrus communis* L.) apple (*Malus communis* L.), cherry (*Prunus avium* L.), almond (*Prunus dulcis* L.) and apricot (*Prunus armeniaca* L.) (Schuster et al., 2013; Yılmaz et al., 2016). The primary target in pomiculture is to get high yields economically. Thus, for successful pollination, fruit set and ultimately high yield, foreign pollinators should be used in self-incompatible fruit species (Halder et al., 2019).

Receptivity of stigma, the survival of ovule and pollen arrival times to ovary is the key parameters of successful pollination and fertilization (Carpenedo et al., 2019). Pollens land on a receptive stigma, germinated pollens then generate a pollen tube and ultimately reach to the surviving ovary to execute

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fertilization. Since the seeds are consumed in stone-fruits, all the bloomed flowers should turn into fruit (100% fruit set) for maximum yields (Dicenta et al., 2000; Khadivi-Khub and Khalili, 2017). Care and maintenance practices, ecology, type of pollinator and variety genetics have direct impacts on yields (Brittain et al., 2014; Klein et al., 2015).

Incompatibility is mostly related to s allele genes with significant impacts on variety of genetics (McCubbin, 2017). These genes not only play a great role in fruit sets but also have significant contributions to genetic diversity in s allele-related plant breeding (Gómez et al., 2019; Liu et al., 2018). Together with s-allele genes, different pollinators also significant effects on fruit mass, shape, size and other parameters. Previous researchers investigated the effects of different pollinators on quality parameters in tangerines (*Citrus reticulata* L.) (Yıldız and Kaplankıran, 2017), cherry (*Prunus avium* L.) (Cırtlık and Beyhan, 2012) and almond (*Prunus dulcis* L.) .

In this study, intra- and inter-species hybridizations were performed in some apricot cultivars and the effects of pollinators on fruit set and **fruit properties** of hybrid combinations were investigated.

Materials and Methods

Materials

Experiments were conducted in collection orchards of Alata Horticultural Research Institute, **between 2018 and 2019 years in Turkey**. The apricot cultivars 'Ninfa,' 'Precoce De Tyrinthe'and 'Palstein' were used as mother parents. The apricot cultivars 'Hacıhaliloğlu,' 'Kabaaşı,' 'Hasanbey' and 'Aprikoz' were used as father parent in intra-species hybridizations; plum cultivars 'Black Amber,' 'Black Splendor' and 'Black Diamond' were used as father parent in inter-species hybridizations. The collection orchard (36°37′28" N, 34°20′12" E) where the experiments were conducted was established in 2004. The orchard has different apricot cultivars and there are three trees from each cultivar. Orchard soils have a silty-loam texture. Trees are about 15 years old. Meteorological data for flowering, pollination and fertilization periods are provided in Table 1.

Method

Pollens of the father parents were collected from the flowers at the balloon stage before the anthers dehiscence. Then, pollens were brushed on emasculated flowers to make hybridizations. Routine

Table 1. Meteorological data for the experimental years.

2018 year								
Wind speed m s^{-1}			Precipitation (mm)		Max. temperature °C		Min. temperature °C	
	February	March	February	March	February	March	February	March
Max.	1.9	4.0	19.0	11.8	21.3	27.3	10.5	15.5
Min.	0,5	0.8	0.8	0.2	16.1	18.2	4.0	6.7
Mean	1.0	1.5	1.57	0.4	18.2	21.0	7.3	9.9
2019 year								
Wind speed m s^{-1}			Precipitation (mm)		Max. temperature °C		Min. temperature °C	
	February	March	February	March	February	March	February	March
Max.	2.6	1.7	146.8	73.0	19.4	22.7	9.9	11.3
Min.	0.8	0.7	0.2	0.2	11.5	15.2	2.3	0.9
Mean	1.4	1.3	5.2	2.3	16.4	18.4	6.1	6.9

cultural practices (irrigation, soil tillage and pruning) were performed accordingly. At the end of dormancy, 3 kg 15–15-15 N-*P*-K per tree was applied.

Fruits were harvested at harvest maturity, and the harvested number of fruits was used to get fruit set ratios for different hybrid combinations. Hybridizations were performed on March 6, 2018 in the first year and March 8, 2019 in the second year; harvests were practiced on May 25, 2018 in the first year and May 20, 2019 in the second year. For **pomological properties**, fruit mass, fruit width, fruit length, peal color, flesh color, water-soluble dry matter (WSDM), flesh and stone ratio, pH, acidity (%), stone width, stone length and stone mass parameters were measured (Son, 2018).

Experimental data were subjected to statistical analyses with the aid of software SPSS 22.0 (IBM Company, USA) and significant means were compared with Duncan's multiple range test at $P < .05$ significance level.

Results and Discussion

Fruit Set Ratios

The greatest fruit set ratio (18.8%) in apricot × apricot intra-species combinations was observed in 'Precoce De Tyrinthe' × 'Hasanbey' hybridizations with 47 fruits. The lowest fruit set ratios (5.2%) were observed in 'P. P. Tyrinthe' × 'Hacıhaliloğlu' and 'P. P. Tyrinthe' × 'Aprikoz' hybrid combinations with 13 fruits **in 2018**(Table 2).

The greatest fruit set ratio (3.6%) in apricot x plum inter-species hybridizations was observed in the 'Precoce De Tyrinthe' x 'Black Diamond' hybrid combination with 11 fruits. The lowest fruit set ratio (0.3%) was observed in the 'Ninfa' x 'Black Amber' combination with only 1 fruit. Fruit set was not observed in the 'Precoce De Tyrinthe' x 'Black Splendor' hybrid combination (Table 2). In 2019, the greatest fruit set ratio (21.8%) in apricot x apricot intra-species hybrid combinations was observed in the 'Ninfa' x 'Hasanbey' hybrid combination with 109 fruits. As compared to the other combinations, less fruit set ratios (4.0%) were observed in 'Ninfa' x 'Hacıhaliloğlu,' 'Ninfa' x 'Aprikoz,' 'Ninfa' x 'Kabaaşı' and 'Palstein' x 'Hasanbey' combinations with 20 fruits in each (Table 3).

In apricot x plum inter-species hybrid combinations, fruit set ratios varied between 6.2% and 0.6% corresponding to 3 and 31 fruits. The greatest value was observed in the 'Precoce De Tyrinthe' x 'Black Amber' combination and the lowest value was seen in the 'Palstein' x 'Black Amber' combination. In inter-species hybrid combinations, fruit set was not observed in 'Ninfa' x 'Black Diamond,' 'Palstein' x 'Black Splendor' and 'Palstein' x 'Black Diamond' combinations (Table 3). Taha and Elsherif (2015) conducted a study about the effects of intra-species hybridizations and different pollinators on fruit set

Table 2. Fruit set ratios of 2018.

Hybrid combination	Number of pollinated flowers	Number of fruit sets	*Fruit set ratio* (%)
Apricot × apricot			
Ninfa × Hasanbey	250	18	7.2
Ninfa × Hacıhaliloğlu	250	14	5.6
Ninfa × Aprikoz	250	24	9.6
Precoce De Tyrinthe × Aprikoz	250	13	5.2
Precoce De Tyrinthe × Hasanbey	250	47	18.8
Precoce De Tyrinthe × Hacıhaliloğlu	250	13	5.2
Apricot × plum			
Ninfa × Black Diamond	300	9	3.0
Ninfa × Black Splendor	300	6	2.0
Ninfa × Black Amber	300	1	0.3
Precoce De Tyrinthe × Black Diamond	300	11	3.6
Precoce De Tyrinthe × Black Amber	300	3	1.0
Precoce De Tyrinthe × Black Splendor	300	0	0.0

Table 3. Fruit set ratios of 2019.

Hybrid combination	Number of pollinated flowers	Number of fruit sets	*Fruit set ratio* (%)
Apricot × apricot			
Ninfa × Hasanbey	500	109	21.8
Ninfa x Hacıhaliloğlu	500	20	4.0
Ninfa x Aprikoz	500	20	4.0
Ninfa x Kabaaşı	500	20	4.0
Precoce De Tyrinthe x Aprikoz	500	36	7.2
Precoce De Tyrinthe x Hasanbey	500	44	8.8
Precoce De Tyrinthe x Hacıhaliloğlu	500	25	5.0
Precoce De Tyrinthe x Kabaaşı	500	60	12.0
Palstein x Hacıhaliloğlu	500	38	7.6
Palstein x Aprikoz	500	30	6.0
Palstein x Hasanbey	500	20	4.0
Palstein x Kabaaşı	500	30	6.0
Apricot × plum			
Ninfa x Black Amber	500	12	2.4
Ninfa x Black Splendor	500	4	0.8
Ninfa x Black Diamond	500	0	0.0
Precoce De Tyrinthe x Black Diamond	500	30	6.0
Precoce De Tyrinthe x Black Amber	500	31	6.2
Precoce De Tyrinthe x Black Splendor	500	20	4.0
Palstein x Black Amber	500	3	0.6
Palstein x Black Splendor	500	0	0.0
Palstein x Black Diamond	500	0	0.0

and quality in apricot and reported fruit set ratios of between 18.0% and 21.7% based on pollinator cultivars. In the present study, apricot intra-species hybridizations yielded similar fruit set ratios.

Inter-species hybridizations between apricot and plum cultivars (*P. armeniaca* × *P. cerasifera*) generally had quite low fruit set ratios (Rubio et al., 2011; Szymajda et al., 2015). As compared to inter-species hybridizations, present intra-species hybridizations also yielded quite low fruit set ratios and fruit set was not observed in wild species. In this sense, the present findings comply with those earlier ones.

Pomological Properties

In intra-species hybrid combinations of 2018, the lowest fruit mass (46.46 g) was observed in 'Precoce De Tyrinthe' x 'Hacıhaliloğlu' combination and the greatest fruit mass (63.99 g) was observed in 'Precoce De Tyrinthe' x 'Hasanbey' hybrid combination (Table 4).

In 2019, the lowest fruit mass (39.71 g) was observed in the Ninfa x Kabaaşı combination and the greatest fruit mass (71.97 g) was observed in the Palstein x Aprikoz combination (Table 5). In intra-species hybrid combinations of 2018, the lowest fruit width (44.12 mm) was obtained from Ninfa x Hasanbey combination, and the greatest fruit width (47.72 mm) was obtained from Precoce De Tyrinthe x Hasanbey combination; in 2019, the lowest fruit width (39.54 mm) was obtained from Ninfa x Kabaaşı combination and the greatest fruit width (50.99 mm) was obtained from Palstein x Aprikoz combination.

Differences in fruit skin and flesh color values of the hybrid combinations, respectively, varied between 2.97 and 2.95 in 2018 and between 3.30 and 3.03 in 2019. The average WSDM content of apricot x apricot combinations was 8.38% in 2018 and 9.01% in 2019.

In 2018, the lowest flesh/stone ratio (14.42) was observed in the Precoce De Tyrinthe x Hacıhaliloğlu hybrid combination and the greatest ratio (20.40) was observed in the Precoce De Tyrinthe x Hasanbey combination. In 2019, the lowest flesh and stone ratio (15.06) was observed in the Palstein x Hasanbey combination and the greatest ratio (28.83) was observed in the Precoce De Tyrinthe x Kabaaşı hybrid combination. The average pH was 3.59 in 2018 and 3.51 in 2019. Ninfa

Table 4. Pomological characteristics of apricot x apricot hybrid combinations in 2018.

Combination	Fruit mass (g)	Fruit length (mm)	Fruit width (mm)	Skin color	Flesh color	WSDM
Ninfa	60.34 ± 8.5	48.27 ± 3.1	46.74 ± 2.9	3.00 ± 0.8	2.30 ± 0.6	10.58 ± 1.3
Precoce De Tyrinthe	52.29 ± 8.7	50.27 ± 3.2	43.67 ± 3.9	2.60 ± 0.5	3.00 ± 0.4	5.86 ± 0.8
Ninfa × Aprikoz	53.96 ± 0.0	43.96 ± 0.0	44.28 ± 0.0	3.00 ± 0.0	3.00 ± 0.0	11.00 ± 0.0
Ninfa x Hacıhaliloğlu	50.56 ± 3.6	47.66 ± 2.9	44.50 ± 3.4	3.50 ± 0.8	3.66 ± 1.0	10.00 ± 0.8
Ninfa x Hasanbey	48.80 ± 0.0	47.64 ± 0.0	44.12 ± 0.0	2.00 ± 0.0	2.00 ± 0.0	7.00 ± 0.0
Precoce De Tyrinthe x Hacıhaliloğlu	46.56 ± 0.0	49.18 ± 0.0	45.01 ± 0.0	3.00 ± 0.0	4.00–0.0	8.00 ± 0.0
Precoce De Tyrinthe x Hasanbey	63.99 ± 2.0	49.35 ± 1.6	47.72 ± 2.6	3.70 ± 0.6	3.20 ± 0.9	8.10 ± 0.7
Precoce De Tyrinthe x Aprikoz	53.26 ± 3.5	48.20 ± 4.7	46.21 ± 2.4	2.00 ± 0.8	2.83 ± 1.4	7.66 ± 1.5
Mean	56.41 ± 9.3	48.78 ± 3.1	45.75 ± 3.3	2.97 ± 0.8	2.95 ± 0.9	8.38 ± 2.0
Combination	Flesh:stone	pH	Acidity (%)	Stone width (mm)	Stone length (mm)	Stone mass (g)
Ninfa	29.66 ± 8.1	3.46 ± 0.0	0.65 ± 0.03	23.66 ± 1.9	27.52 ± 2.4	2.03 ± 0.3
Precoce De Tyrinthe	23.84 ± 5.5	3.64 ± 0.1	0.75 ± 0.07	31.09 ± 1.3	22.97 ± 2.0	2.12 ± 0.2
Ninfa x Aprikoz	15.30 ± 0.0	3.61 ± 0.0	0.77 ± 0.00	24.03 ± 0.0	28.98 ± 0.0	3.31 ± 0.0
Ninfa x Hacıhaliloğlu	14.72 ± 2.5	3.65 ± 0.2	0.50 ± 0.05	22.84 ± 1.3	29.20 ± 1.3	3.21 ± 0.2
Ninfa x Hasanbey	15.43 ± 0.0	3.56 ± 0.0	0.72 ± 0.00	23.93 ± 0.0	27.85 ± 0.0	2.97 ± 0.0
Precoce De Tyrinthe x Hacıhaliloğlu	14.42 ± 0.0	3.52 ± 0.0	0.57 ± 0.00	22.52 ± 0.0	29.69 ± 0.0	3.02 ± 0.0
Precoce De Tyrinthe x Hasanbey	20.40 ± 2.3	3.55 ± 0.2	0.67 ± 0.08	22.21 ± 1.4	27.67 ± 1.9	3.00 ± 0.2
Precoce De Tyrinthe x Aprikoz	17.32 ± 3.8	3.64 ± 0.1	0.53 ± 0.07	22.64 ± 0.7	27.63 ± 2.1	2.94 ± 0.3
Mean	21.70 ± 7.1	3.59 ± 0.2	0.62 ± 0.1	24.73 ± 3.7	26.87 ± 2.9	2.62 ± 0.5

(WDSM: Water Soluble Dry Matter).

Table 5. Pomological characteristic apricot x apricot hybrid combinations in 2019.

Combination	Fruit mass (g)	Fruit length (mm)	Fruit width (mm)	Skin color	Flesh color	WSDM
Ninfa	62.36 ± 10.5b	47.92 ± 3.2def	46.54 ± 2.9bc	3.20 ± 0.7defg	2.20 ± 0.7gh	10.70 ± 1.0bc
Palstein	78.74 ± 7.6a	53.14 ± 3.0a	52.37 ± 2.8a	4.05 ± 0.6ab	4.50 ± 0.6a	11.82 ± 1.6a
Precoce De Tyrinthe	54.88 ± 8.6bc	50.09 ± 2.8bcd	44.89 ± 2.7 cd	2.90 ± 0.6 g	3.15 ± 0.3 cd	6.16 ± 1.1 h
Ninfa x Aprikoz	44.81 ± 18.3e	42.09 ± 5.7i	38.69 ± 5.4e	3.50 ± 0.6def	2.55 ± 05fg	11.35 ± 1.6ab
Ninfa x Hacıhaliloğlu	53.25 ± 8.7 cd	46.56 ± 3.2efg	44.60 ± 3.1 cd	3.60 ± 0.5 cde	3.10 ± 0.5 cde	10.19 ± 2.6 cde
Ninfa x Hasanbey	55.75 ± 11.3bc	46.02 ± 3.2 fg	43.36 ± 4.1d	1.80 ± 0.6i	1.45 ± 0.5i	10.86 ± 1.1abc
*Ninfa x Kabaaşı	39.71 ± 14.3e	41.60 ± 4.1i	39.54 ± 3.9e	2.40 ± 0.5 h	1.85 ± 0.4 h	9.26 ± 1.9e
Palstein x Aprikoz	71.97 ± 11.8a	52.30 ± 2.5ab	50.99 ± 3.5a	3.95 ± 0.6abc	3.95 ± 0.8b	9.48 ± 1.9de
Palstein x Hacıhaliloğlu	70.88 ± 9.9a	51.95 ± 2.6ab	50.66 ± 2.4a	4.25 ± 0.7a	4.05 ± 0.6b	10.97 ± 1.9abc
Palstein x Hasanbey	61.22 ± 19.3bc	48.64 ± 6.0 cde	47.01 ± 7.1bc	3.65 ± 0.4bcd	3.35 ± 0.8 c	6.36 ± 1.1gh
Palstein x Kabaaşı	71.60 ± 12.1a	52.10 ± 3.5ab	50.37 ± 2.9a	4.10 ± 0.7a	4.10 ± 0.6b	10.48 ± 2.1bcd
Precoce De Tyrinthe x Hacıhaliloğlu	39.88 ± 13.7e	43.22 ± 4.6hi	39.80 ± 5.5e	3.15 ± 0.8efg	2.75 ± 0.5def	6.32 ± 1.2gh
Precoce De Tyrinthe x Hasanbey	44.65 ± 6.8e	45.36 ± 2.5fgh	42.91 ± 2.6d	3.05 ± 0.9fg	2.75 ± 0.5def	7.69 ± 0.7 f
*Precoce De Tyrinthe x Kabaaşı	60.05 ± 9.6bc	50.56 ± 2.6abc	47.68 ± 3.2b	3.20 ± 0.4defg	2.70 ± 0.5ef	7.36 ± 1.1fg
*Precoce De Tyrinthe x Aprikoz	46.33 ± 14.6de	44.60 ± 4.4gh	39.81 ± 5.0e	3.15 ± 0.4efg	3.00 ± 0.7cde	6.15 ± 0.7 h
Mean	57.07 ± 17.0	47.74 ± 5.2	45.28 ± 5.9	3.30 ± 0.9	3.03 ± 1.0	9.01 ± 2.5
Combination	Flesh:stone	pH	Acidity (%)	Stone width (mm)	Stone length (mm)	Stone mass (g)
Ninfa	30.05 ± 9.7a	3.53 ± 0.0abc	0.69 ± 0.05ab	24.52 ± 1.9bc	28.95 ± 2.0def	2.10 ± 0.3de
Palstein	20.80 ± 4.3 cdef	3.34 ± 0.0bc	0.67 ± 0.07ab	22.52 ± 2.1d	28.56 ± 3.6ef	3.70 ± 0.6b
Precoce De Tyrinthe	24.96 ± 4.8bc	3.54 ± 0.2abc	0.74 ± 0.01ab	22.96 ± 1.6 cd	30.95 ± 1.9abc	2.13 ± 0.2de
Ninfa x Aprikoz	16.89 ± 9.8 gh	3.63 ± 0.0ab	0.70 ± 0.05ab	28.65 ± 3.3a	23.43 ± 3.2 h	2.81 ± 0.9 c
Ninfa x Hacıhaliloğlu	23.21 ± 5.1 cd	3.68 ± 0.0a	0.71 ± 0.12ab	24.24 ± 0.9bc	29.09 ± 1.4def	2.22 ± 0.2d
Ninfa x Hasanbey	22.13 ± 4.7cde	3.53 ± 0.0abc	0.69 ± 0.05ab	25.71 ± 1.2b	30.53 ± 1.0abcd	2.42 ± 0.2d
*Ninfa x Kabaaşı	16.36 ± 6.2gh	3.60 ± 0.1ab	0.64 ± 0.03b	23.53 ± 3.1 cd	28.90 ± 3.8def	2.33 ± 0.3d
Palstein x Aprikoz	18.47 ± 4.0 fgh	3.37 ± 0.0abc	0.66 ± 0.05b	23.54 ± 1.1 cd	29.82 ± 1.2bcde	3.75 ± 0.4b
Palstein x Hacıhaliloğlu	18.05 ± 3.6fgh	3.42 ± 0.1abc	0.70 ± 0.02ab	23.18 ± 1.5 cd	29.33 ± 1.5cdef	3.75 ± 0.3b
Palstein x Hasanbey	15.06 ± 9.1 h	3.44 ± 0.1abc	0.74 ± 0.05ab	24.51 ± 3.2bc	28.30 ± 3.2ef	4.18 ± 1.1a
Palstein x Kabaaşı	17.56 ± 3.7fgh	3.25 ± 0.1 c	0.65 ± 0.10b	23.36 ± 1.8 cd	29.03 ± 2.1def	3.92 ± 0.5 ba
Precoce De Tyrinthe x Hacıhaliloğlu	21.07 ± 8.0cdef	3.63 ± 0.1ab	0.73 ± 0.08ab	20.36 ± 1.7e	27.44 ± 2.2fg	1.83 ± 0.2ef
Precoce De Tyrinthe x Hasanbey	24.91 ± 5.3bc	3.61 ± 0.1ab	0.79 ± 0.11a	25.43 ± 1.9b	32.16 ± 3.0a	1.75 ± 0.2f
*Precoce De Tyrinthe x Kabaaşı	28.83 ± 8.0ab	3.64 ± 0.1ab	0.77 ± 0.03ab	24.32 ± 3.1bc	31.34 ± 3.9ab	2.08 ± 0.4de
*Precoce De Tyrinthe x Aprikoz	20.06 ± 6.1def	3.53 ± 0.3abc	0.77 ± 0.04ab	19.94 ± 2.1e	26.40 ± 2.3 g	2.21 ± 0.3d
Mean	21.23 ± 7.7	3.51 ± 0.1	0.71 ± 0.07	23.78 ± 2.9	28.95 ± 3.2	2.74 ± 0.9

* – sufficient number of fruit sets was not achieved in these combinations in 2018.
Different lower case letters show statistically significant differences between the columns of the year to which they belong ($p < 0.05$).
(WDSM: Water Soluble Dry Matter).

x Hacıhaliloğlu combination was found to be prominent for pH (3.68). Average acidity was measured as 0.62 in 2018 and 0.71 in 2019. Precoce De Tyrinthe x Hasanbey combination had greater acidity values than the other combinations.

In apricot x apricot intra-species hybrids, there were differences in stone parameters of mother parent and normally pollinated fruits of hybrid combinations in both years. In both years, the greatest stone widths (24.03 and 28.65 mm) were observed in Ninfa x Aprikoz hybrid combinations. The greatest stone length was observed in the Precoce De Tyrinthe x Hacıhaliloğlu combination (29.69 mm) in 2018 and in Precoce De Tyrinthe x Hasanbey combination (32.16 mm) in 2019. The greatest stone mass was observed in the Ninfa x Aprikoz combination (3.31 g) in 2018 and in Palstein x Hasanbey combination (4.18 g) in 2019 (Tables 4 and 5).

In 2018, in Apricot x Plum hybrid combinations, average fruit mass was 30.73 g, fruit length was 40.19 mm, fruit width was 36.25 mm, skin color was 2.00, flesh color was 3.00, WSDM was 9.00%, flesh/stone ratio was 11.24, pH was 3.89, acidity was 0.63%, stone width was 21.82 mm, the stone length was 25.75 mm and stone mass was 2.51 g (Table 6).

In 2019, among the inter-species hybrid combinations, Palstein x Black Amber was found to be prominent for fruit mass (70.58 g), fruit width (52.25 mm), fruit length (50.37 mm), skin color (3.80) and flesh color (4.10) values. As compared to open-pollinated fruits, mother parents did not have positive effects on WSDM and flesh and stone ratios. The greatest WSDM content (10.89%) was observed in the Palstein x Black Amber combination and the greatest flesh/stone ratio (24.56) was observed in the Precoce De Tyrinthe x Black Amber combination. The greatest pH (3.85) was observed in the Ninfa x Black Splendor combination.

As it was in the other parameters of inter-species hybrid combinations, the Palstein x Black Amber combination had greater stone mass, stone length and stone width values (Table 7).

Previous researchers reported fruit mass values of some early apricot cultivars as between 37.7 and 58.83 g (Son, 2018), fruit lengths as between 42.21 mm (Çağataybey) and 50.13 mm (Alatayıldızı) (Bircan et al., 2010), fruit widths as between 34.81 and 49.68 mm (Karaat and Serçe, 2019).

WSDM contents of some early apricot cultivars were reported as between 11.06% and 14.06% (Son and Bahar, 2018), flesh and stone ratios as between 10.4 and 20.8 (Bilgin et al., 2016), pH values as between 3.31 and 4.25 (Özdoğru et al., 2014), titratable acidity values as between 0.2% and 0.87% (Polat, 2018), stone mass values as between 1.75 and 2.43 g (Bilgin et al., 2016). Present findings comply with the results of earlier studies. Differences in some parameters are mostly attributed to differences in cultivars, ecological conditions and analysis methods.

Conclusion

Hybridization breeding is commonly used especially in fruit breeding programs. Despite a low chance of success, the inter-species hybridization technique may have significant contributions to breeding studies through improving genetic variation and diversity. This study was conducted to investigate the effects of different apricot x apricot (intra-species) hybrid combinations and apricot x plum (inter-species) hybrid combinations on fruit set and **pomological properties** of stone-fruit species. Resultant hybrid seeds may guide further breeders in developing new genotypes with the potential of candidate cultivar and rootstock in pomiculture. Present findings may also guide further research to be conducted on intra and inter-species hybridizations of apricots and plums.

Table 6. Pomological characteristic apricot x plum hybrid combinations in 2018.

Combination	Fruit mass (g)	Fruit length (mm)	Fruit width (mm)	Skin color	Flesh color	WSDM
Ninfa	60.34 ± 8.5	48.27 ± 3.1	46.74 ± 2.9	3.00 ± 0.8	2.30 ± 0.6	10.58 ± 1.3
Precoce De Tyrinthe	52.29 ± 8.7	50.27 ± 3.2	43.67 ± 3.9	2.60 ± 0.5	3.00 ± 0.4	5.86 ± 0.8
Ninfa x Black Splendor	30.73 ± 0.0	40.19 ± 0.0	36.25 ± 0.0	2.00 ± 0.0	3.00 ± 0.0	9.00 ± 0.0
Mean	55.09 ± 10.7	48.84 ± 3.7	44.78 ± 4.1	2.80 ± 0.6	2.61 ± 0.6	8.25 ± 2.5
Combination	Flesh:stone	pH	Acidity (%)	Stone width (mm)	Stone length (mm)	Stone weight (g)
Ninfa	29.66 ± 8.1	3.46 ± 0.0	0.65 ± 0.03	23.66 ± 1.9	27.52 ± 2.4	2.03 ± 0.3
Precoce De Tyrinthe	23.84 ± 5.5	3.64 ± 0.1	0.75 ± 0.07	31.09 ± 1.3	22.97 ± 2.0	2.12 ± 0.2
Ninfa x Black Splendor	11.24 ± 0.0	3.89 ± 0.0	0.63 ± 0.00	21.82 ± 0.0	25.75 ± 0.0	2.51 ± 0.0
Mean	26.01 ± 7.9	3.60 ± 0.1	0.69 ± 0.07	21.82 ± 0.0	25.13 ± 3.1	2.09 ± 0.2

(WDSM: Water Soluble Dry Matter).

Table 7. Pomological characteristic apricot x plum hybrid combinations in 2019.

Combination	Fruit mass (g)	Fruit length (mm)	Fruit width (mm)	Skin color	Flesh color	WSDM
Ninfa	62.36 ± 10.5c	47.92 ± 3.2bc	46.54 ± 2.9b	3.20 ± 0.7b	2.20 ± 0.7d	10.70 ± 1.0a
Precoce De Tyrinthe	54.88 ± 8.6 cd	50.09 ± 2.8ab	44.89 ± 2.7bc	2.90 ± 0.6b	3.15 ± 0.3bc	6.16 ± 1.1d
Palstein	78.74 ± 7.6a	53.14 ± 3.0a	52.37 ± 2.8a	4.05 ± 0.6a	4.50 ± 0.6a	11.82 ± 1.6a
Ninfa x Black Splendor	34.37 ± 18.0f	42.60 ± 5.6d	37.60 ± 6.6e	2.25 ± 0.5e	1.75 ± 0.5e	9.50 ± 2.7b
*Ninfa x Black Amber	42.23 ± 10.6e	44.03 ± 4.0d	40.87 ± 4.1d	2.33 ± 0.6e	1.66 ± 0.4e	8.25 ± 0.9 c
Palstein x Black Amber	70.58 ± 4.4b	52.25 ± 4.6a	50.37 ± 5.4a	3.80 ± 0.6a	4.10 ± 0.7a	10.89 ± 2.0a
*Precoce De Tyrinthe x Black Diamond	21.18 ± 3.8g	33.57 ± 2.2e	31.95 ± 2.3 f	2.50 ± 0.5cd	2.85 ± 0.4 c	7.85 ± 1.3 c
*Precoce De Tyrinthe x Black Splendor	48.09 ± 12.9de	45.21 ± 6.0cd	41.85 ± 5.9 cd	2.85 ± 0.3b	3.00 ± 0.3bc	8.12 ± 1.3 c
*Precoce De Tyrinthe x Black Amber	51.58 ± 15.4d	45.96 ± 4.6 cd	42.01 ± 4.9 cd	2.95 ± 0.6b	3.45 ± 0.5b	7.58 ± 1.6c
Mean	**53.80 ± 19.6**	**46.55 ± 7.0**	**43.85 ± 7.3**	**3.08 ± 0.8**	**3.15 ± 1.0**	**8.97 ± 2.3**
Combination	Flesh:stone	pH	Acidity (%)	Stone width (mm)	Stone length (mm)	Stone weight (g)
Ninfa	30.05 ± 9.7a	3.53 ± 0.0bcd	0.69 ± 0.05	24.52 ± 1.9bc	28.95 ± 2.0de	2.10 ± 0.3d
Precoce De Tyrinthe	24.96 ± 4.8b	3.54 ± 0.2bcd	0.74 ± 0.01	22.96 ± 1.6 cd	30.95 ± 1.9 c	2.13 ± 0.2 cd
Palstein	20.80 ± 4.3bc	3.34 ± 0.0de	0.67 ± 0.07	22.52 ± 2.1e	28.56 ± 3.6e	3.70 ± 0.6a
Ninfa x Black Splendor	16.88 ± 9.3 c	3.85 ± 0.0a	0.68 ± 0.07	20.57 ± 1.1e	27.87 ± 1.2e	2.00 ± 0.4d
*Ninfa x Black Amber	16.59 ± 5.1 c	3.44 ± 0.1 cde	0.70 ± 0.08	23.50 ± 1.8 cd	28.17 ± 2.3e	2.44 ± 0.3c
Palstein x Black Amber	20.83 ± 4.8bc	3.24 ± 0.1e	0.65 ± 0.08	29.31 ± 1.3a	33.34 ± 1.8a	3.34 ± 0.5b
*Precoce De Tyrinthe x Black Diamond	9.62 ± 3.2d	3.74–0.1ab	0.72 ± 0.04	24.32 ± 3.1c	31.34 ± 3.9bc	2.08 ± 0.4d
*Precoce De Tyrinthe x Black Splendor	20.92 ± 5.4bc	3.67 ± 0.1abc	0.63 ± 0.12	26.08 ± 1.3b	33.04 ± 1.4ab	2.21 ± 0.3 cd
*Precoce De Tyrinthe x Black Amber	24.56 ± 8.2b	3.65 ± 0.0abc	0.66–0.06	22.98 ± 2.2 cd	30.56 ± 0.9 cd	2.01 ± 0.1d
Mean	**21.16 ± 8.2**	**3.57 ± 0.2**	**0.69 ± 0.0**	**24.48 ± 2.9**	**30.67 ± 3.0**	**2.49 ± 0.7**

* – sufficient number of fruit sets was not achieved in these combinations in 2018.
Different lower case letters show statistically significant differences between the columns of the year to which they belong ($p < 0.05$).
(WDSM: Water Soluble Dry Matter).

Acknowledgments

Authors thanks Erciyes University for financial support.

Funding

This study was supported by the Scientific Research Projects Department of Erciyes University (Project No: FDK-2018-8044).

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