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Research paper

Introduction of Attar a new early-ripening sweet cherry cultivar with suitable fruit quality

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Abstract

Introducing new sweet cherry cultivars with early ripening time is one of the most important goals of cherry breeding programs in Iran. The Attar cultivar was selected from the native sweet cherry germplasms of the Khorasan Razavi province by implementing eight research projects for 21 years since 1998. Evaluation of the vegetative, reproductive, and pomological characteristics of the genotypes along with other cultivars during 2005-2020 led to the introduction of the Attar cultivar. The results showed that Attar had semi-spreading tree habits with a moderate degree of branching. The time of the first flowering for Attar was in the second week of April. Results showed that this cultivar was self-incompatible. Siyah-e-Mashhad, Sweet Heart, and Dovomras-e-Mashhad cultivars were suitable pollinizers for the Attar cultivar. The harvesting time of Attar was in the first week of June. The average fruit weight of the Attar cultivar (7.73 g) was higher than those of the Shandiz (7.23 g) and Toos (6.87 g) cultivars. Also, the total soluble solids in Attar (19.87%) were higher than the Shandiz (16.63%) and Toos (17.13%) cultivars. The fruit yield of Attar in the economic fruiting stage was 40 kg per tree, which was higher than the Shandiz cultivar (22.43 kg). Fruit cracking disorder in the Attar cultivar was lower than other cultivars. Attar has a high economic value and therefore the development of this cherry cultivar can play an important role in increasing the income of cherry producers.

Keywords: Attar; cultivar; phenological and pomologhical traits; sweet cherry; yield

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Introduction

Sweet cherry (*Prunus avium* L.) is a fruit that is appreciated worldwide and is economically attractive, providing a high income for producers. Cherries are mainly consumed fresh (Li *et al*. 2018). Besides their recognized good taste and appealing color, sweet cherries have nutritional and health-promoting characteristics due to their richness in organic acids, sugars, vitamins, minerals, volatile compounds, and antioxidants compounds (e.g. melatonin and dietary phenolic compounds), as well as their fiber content (Ceccarelli *et al*. 2018; Jia *et al*. 2019). Indeed, consumer demand has greatly increased in recent years, leading to a current increase in cherry agricultural production (Ganopoulos *et al*. 2013; Faienza *et al*. 2020).

Iran is the fifth largest producer of cherries in the world after Turkey, USA, Chile, and Uzbekistan with an annual production of 164,080 tons of cherries (FAO 2020). Cherries play an important role in the Iranian fruit industry for

several reasons. One of the most important reasons is the suitable climatic conditions (relatively cold winters and dry summers) in most regions of Iran for growing these fruits. In addition, different forms of cherry consumption such as fresh food, compote, and jam help to supply it in all seasons and its successful trade (Ganji Moghaddam and Bouzari 2010).

Several local varieties have been selected from the natural cherry populations based on the agronomical and pomological potential of the genotypes. In the last decades, a large number of new sweet cherry cultivars with valuable pomological and agronomical characteristics, including self-compatibility and the medium chilling requirement, have been established (Benková *et al*. 2017; Sansavini and Lugli 2008). The selected cultivars show distinctive agronomic characteristics such as low susceptibility to fruit cracking, high levels of soluble solids, early fruit maturity, and great rusticity (Pérez-Sánchez *et al*. 2008). Currently, in more than 70% of Iran's cherry orchards, Siyah-e-Mashhad and Takdane are two dominant cultivars. These cultivars are ripening from late June to mid-July. Therefore, to supply consumer requirements, create a balance in supply and demand, and increase the income of cherry producers in the country, it is necessary to modify and introduce new desirable cultivars with different ripening ranges. For this purpose, accessing very early, early, mid, and late ripening varieties is one of the most important goals pursued in Iran's cherry research. In 2015, the first very early domestic cultivar, was named Adli (Ganji Moghadam *et al*. 2017), and in 2019, the early cultivars Shandiz and Toos were introduced. In the continuation of cherry breeding projects, an early ripening genotype with desirable characteristics was proposed as a new cultivar. Replacing some of the old cherry cultivars with new early-ripening cultivars can play an important role in increasing the income of Iran's cherry growers. Therefore, this paper aimed to describe and introduce Attar as a new early ripening sweet cherry cultivar.

Materials and Methods

The genetic origin of the Attar cultivar is not known exactly. This genotype was found in one of the old gardens of Torghabeh villages located in Torghabeh and Shandiz towns (59° 17' N; 36° 32' E), northeast of Iran/Mashhad, with an average altitude of about 1176 m. The mean temperature for the growing season was 13.4 °C and total seasonal precipitation was 239.7 mm. The nursery soil was sandy loam with low organic matter. Drip irrigation was applied in the nursery. The main method used to develop the Attar cultivar was to select it from the native cherry germplasms of the Khorasan Razavi province. The research project related to the Attar cultivar was implemented in 1998. In this project, identification, collection, and evaluation of the cherry germplasm were performed in different regions of the Khorasan Razavi province. During the identification and collection of cherry genotypes, it was found that some of them were completely different from others. In the first five years of the project, the selected genotype was planted in the Golmakan Agricultural Research Station and the experiment was carried out in the form of an augemented design with five trees per plot. From the sixth year on, vegetative, reproductive, and pomological characteristics of

cultivars were determined by the International Cherry Descriptor (UPOV 2008) until the end of 2019. Also, from 2017 to 2019, the characteristics of the promising Attar genotype were compared with those of some early and mid-ripening cherry cultivars in a randomized complete block design with three replications.

All phenological, morphological, and pomological traits of the promising Attar cultivar were compared with those of Adli, Shandiz, Toos, Siah-e-Ghazvin, Pishras-e-Mashhad, and Delamarka cultivars using the description of cherry specific traits (UPOV 2008). To analyze the characteristics of the promising genotype, a DUS test (distinctness, uniformity, stability) was also conducted. Flower phenology stages were recorded based on Tzoner and Yamaguchi (1999). For determination of (in)compatibility and pollinizer, three branches per tree, each with approximately 100 flowers, were selected in different directions. Then, they were marked and isolated by color and label. One of the branches was isolated to allow natural self-pollination to occur. In each replicate, a separate branch was marked without being isolated so that it can be pollinated freely (Ganji Moghaddam *et al*. 2014). For artificial pollination, the isolated flowers of the above cultivars were pollinated with their own pollen grains and pollen grains from eight cultivars (i.e. Surati-e-Lavasan, Sefid-90, Dovomras-e-Mashhad, Sunburst, Siah-e-Mashhad, Sweet Heart, Bing, Haj Yousefi). The stigmas of the flowers were drawn and pollinated using a special brush for pollen grains. At all stages of pollination, hands and equipment were disinfected with ethyl alcohol to prevent contamination of pollen grains. To ensure, pollination was performed again 24 hours later and the branches were isolated again. After pollination, the final fruit set was determined based on the following equation (Westwood 1993):

Fruit set percent = (The number of fruits/The number of pollinated flowers) × 100

Pomological characteristics such as fruit weight and stone weight were measured and recorded by a digital scale. The percentage of soluble solids was measured with a hand-refractometer at room temperature (in the range of 18 to 23 ℃). Total acid content was measured by titration of sodium hydroxide (0.1 N) based on the predominant acidity of cherry fruit (i.e. malic acid).

At the end of the growing season, the average vegetative growth of six branches of each tree was measured in different directions. Leaf length, leaf width, leaf length to leaf width ratio, petiole length, peduncle length, and peduncle thickness were measured by a caliper.

Data analysis

The analysis of variance was performed based on a randomized complete block design with three replications, and the means were compared using Duncan's multiple range test at a 5% probability level. The data were analyzed by MSTAT-C software, version 14.2.

Results and Discussion

Morphological characteristics

Characteristics of the early Attar cultivar and its growth status from planting time to 2020 were evaluated in Mashhad, Iran. Research showed that this cultivar has semi-spreading tree habits and a moderate degree of branching, sprouting, and

normal internode length.

Phenological characteristics

The flower characteristics and phenological stages of flowering were determined based on observational notes during the flowering period. The results of examining some of the flower nominal characteristics showed that the early Attar cultivar has five sepals, five petals, and 25-35 stamens. The shape of the petals was round and their arrangement was of the middle type (Figure 1).

Based on the phenological data, the beginning of flowering of the early Attar cultivar occured in the second week of April and it entered the full bloom stage six days later. The time of the beginning of flowering of Attar was about 5-7 days later than the Adli, Shandiz, and Toos cultivars (Table 1). It has been reported that the sweet cherry is characterized by a short period between the start and full of flowering and the duration of flowering from six to 15 days. On the other hand, our results were in agreement with the results of Corneanu *et al*. (2020). Garcia *et al*. (2014) noted that the early and middle flowering times are important to produce enough flowers for a normal early sweet cherry crop.

Self-incompatibility

A significant difference was observed between the self-pollination mode and free pollination in terms of fruit set percentage. The results showed that the Attar cultivar needed a suitable pollinizer cultivar to produce fruit (Figure 2).

Most sweet cherry cultivars are self-incompatibe. Among the fruit trees, the most severe case of incompatibility belongs to cherries. In commercial orchards, due to the severity of self-incompatibility and the small size of fruits, more pollen trees are needed to increase the percentage of fruit set compared to apple and pear trees.

Effect of pollinizer cultivars on fruit set percentage of Attar

The results of the analysis of variance showed a significant difference among pollen types for the fruit set percentage of Attar at the 1% probability level (Table 2). Among the eight pollinizers, pollens of the Siah-e-Mashhad cultivar with an average of 43.80%, Sweet Heart with an average of 38.45%, and the Dovomras-e-Mashhad with an average of 36.03% were suitable pollinizer cultivars for the Attar cultivar (Figure 3) Therefore, for the construction of new orchards with Attar, it is recommended to use the Siah-e-Mashhad and Sweet Heart cultivars with the planting arrangement of 4:2 or at least 10% of the original cultivar.

Fruit ripening time

In terms of the fruit harvesting time, Attar was different than the Adli, Shandiz, Toos, and Delamarka cultivars. In other words, Attar can be harvested one week after the introduced early cultivars such as Shandiz and Toos (i.e. the first week of June) (Table 3). In this regard, this cultivar can play an important role in developing the range of early-ripening cherry cultivars in Iran.

Fruit cracking

Fruit cracking ia a main concern in sweet cherry production. Our result revealed that Attar was more

Figure 1. The vegetative and reproductive characteristics of the Attar sweet cherry cultivar.

Table 1. Comparison of the beginning and end of the flowering time of Attar with early sweet cherry cultivars averaged over seven years (2014-2020).

Cultivar	Time of the beginning of flowering	Full bloom	End of flowering
Adli	March 29	6 April	10 April
Shandiz	30 March	6 April	12 Aril
Toos	27 March	5 April	12 April
Siyah-e-Mashhad	9 April	15 April	22 April
Takdane	10 April	17 April	26 April
Attar	4 April	11 April	17 April

Table 2. Analysis of variance of the fruit set percentage for the Attar sweet cherry cultivar.

SOV	df	Mean squares
Replication	2	3.959^{ns}
Cultivar	9	358.934^{**}
Error	18	14.188
CV		12.50

*,**Significant at 5% and 1%probability levels, respectively.

Table 3. Comparison of the ripening time of Attar with early sweet cherry cultivars averaged over seven years (2014-2020).

Cultivar	Harvest time						
	2014	2015	2016	2017	2018	2019	2020
Delamarka	15 May	13 May	10 May	20 May	14 May	13 May	15 May
Adli	14 May	8 May	8 May	10 May	10 May	7 May	10 May
Toos	16 May	17 May	15 May	18 May	19 May	22 May	17 May
Shandiz	14 May	12 May	15 May	12 May	14 May	15 May	18 May
Siyah-e-Ghazvin	22 May	26 May	19 May	26 May	24 May	18 May	23 May
Attar	23 May	25 May	27 May	24 May	21 May	22 May	26 May
Siyah-e-Mashhad	20 June	18 June	22 June	15 June	20 June	18 June	23 May
Takdane	1 July	29 June	3 July	27 June	6 July	29 June	1 July

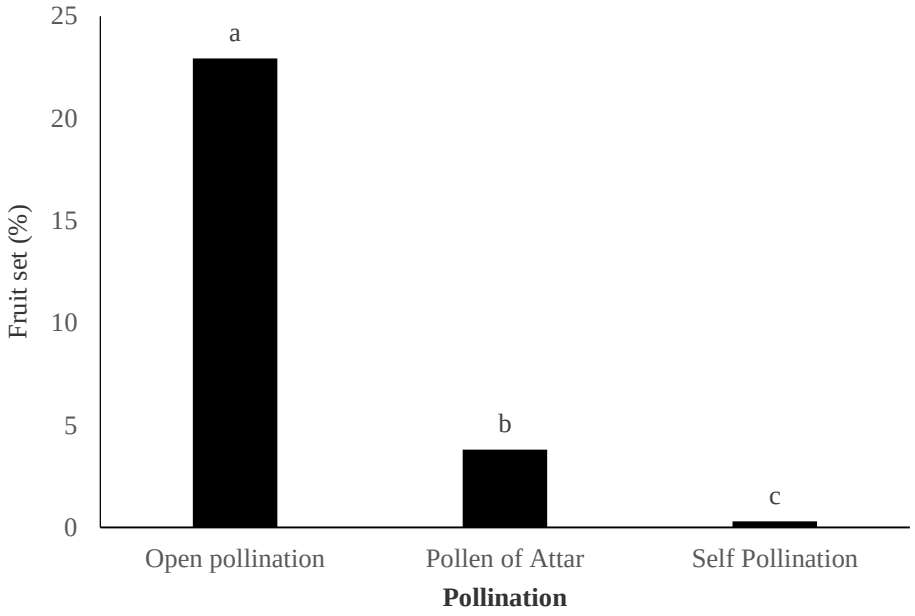

Figure 2. Comparison of the effect of controlled pollination on fruit set percentage of the Attar sweet cherry cultivar.

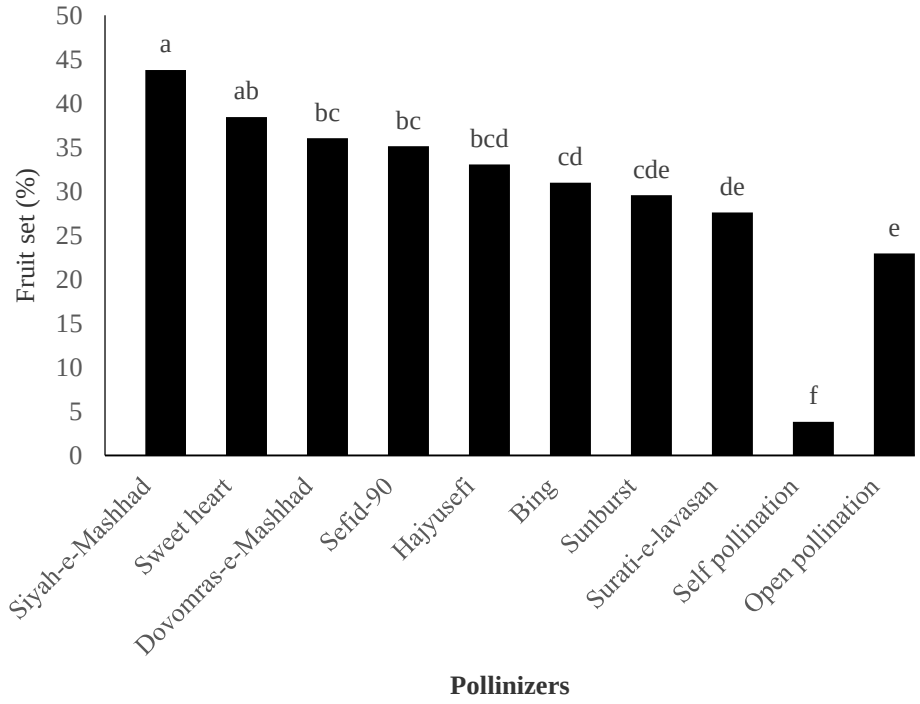

Figure 3. Effect of pollinizers on the fruit set percentage of the Attar sweet cherry cultivar.

tolerant to fruit cracking than other cultivars (data not shown). Pereira (2020) also indicated that the effect of genotype on fruit cracking is more important than other factors.

Pomological and biochemical traits

Based on the analysis of variance, Attar was significantly different from other cultivars for some pomological and biochemical traits of the

fruits (Data not provided). Attar with an average fruit weight of 7.73 g had a higher average weight compared to the Shandiz and Toos cultivars that were introduced in 2019. Early cultivars usually have a lower average fruit weight due to the short growing season. However, due to its large fruit weight, this cultivar is favored (Figure 4).

Fruit peduncle length is one of the traits used in identifying cherry cultivars. The multi-year evaluation showed that Attar with a 3.1 cm peduncle length compared to Adli and Shandiz with 3.6 cm and Toos with 2.4 cm had shorter and longer fruit peduncle lengths, respectively. In other words, this cultivar belongs to the medium peduncle length group. In evaluating the fruit peduncle thickness in early cherry cultivars, the thickness of the fruit peduncle varied between 1 and 1.54 mm. The maximum and minimum thickness of the fruit peduncle was observed in the Attar and Delamarka cultivars, respectively. Cultivars with thick fruit peduncles have shown higher transportability and are more tolerant to mechanical damage. Attar had a larger peduncle thickness compared to the existing early cultivars, which is a good feature of this cultivar. Comparing the stone weight of the early cherry cultivars with Attar, the results showed that Attar with 0.21 g compared to the Shandiz cultivar, had lower stone weight. In general, the Attar cultivar had a higher ratio of fruit weight to stone weight (Table 4),

The results of the biochemical characteristics of the fruit are shown in Table 4. The total soluble solids value in Attar with 19.87% was higher than other early cultivars such as Adli (16.9%), Shandiz (16.63%), and Toos (17.13%). The highest juice pH was in the Delamarka cultivar and Attar with an average of 3.76 and the lowest juice pH was in the Toos cultivar with an average of 3.43. Titrable acidity varied among cultivars and the highest titrable acidity (1.15%) was in the Adli cultivar. The data concerning the chemical composition of the fruits is consistent with previous findings of Vursavus *et al*. (2006). The chemical composition of fruits represents a major source of antioxidant compounds (Usenik *et al*. 2008), so consumers have an increasing interest in fruits in recent years (Khanizadeh *et al*. 2007). The soluble dry substance and the titratable acidity content are considered extremely important to determine the fruits' taste, reflecting a balance between the sweet and the sour taste of the fruits (Crisosto *et al*. 2002). The recorded values on the soluble dry substance content of the fruits are in line with those of other studies (e.g. Janes *et al*. 2010; Papapetros *et al*. 2018).

Evaluation of leaf traits

Evaluation of the leaf blade length, leaf blade width, leaf blade length to leaf blade width ratio, and petiole length in the early cultivars showed that the highest and lowest leaf blade lengths belonged to the Delamarka cultivar with an average of 14.26 cm, and the Attar cultivar with an average of 10.51 cm, respectively. The highest leaf blade width was in the Delamarka cultivar with an average of 6.53 cm and the Attar cultivar with an average of 5.52 cm. Leaf blade length to leaf blade width ratio varied between 1.72 to 2.38, and Attar had a ratio of 1.72. Petiole length ranged from 3.14 to4.73 cm between cultivars, with the highest petiole length in Delamarka (4.73) and the lowest in Attar(3.14 cm) (Table 5). These result are in agreement with Baji

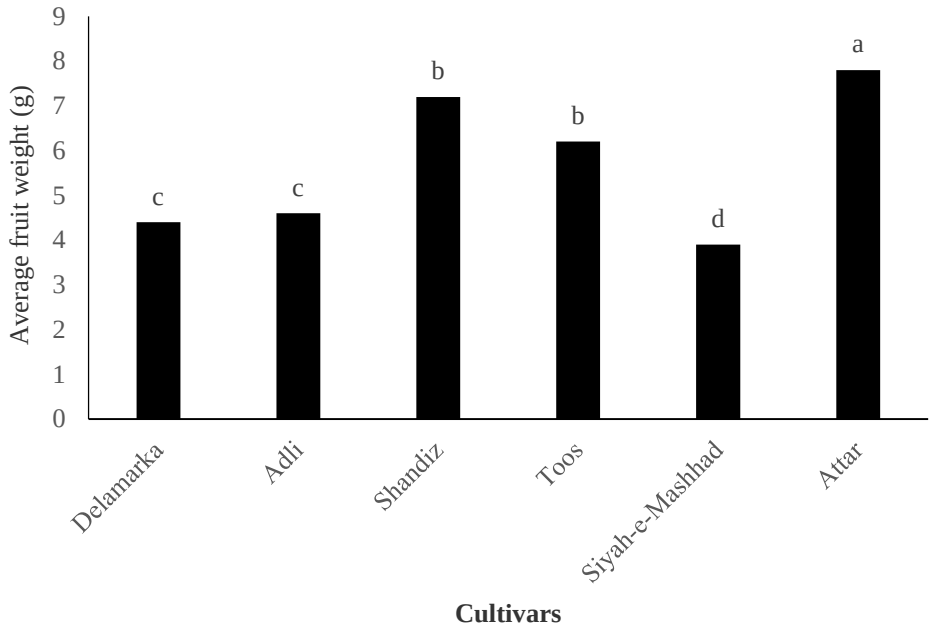

Figure 4. Comparison of the fruit weight of Attar with early sweet cherry cultivars averaged over seven years (2014-2020).

Table 4. Comparison of the pomological and biochemical traits of Atar with early sweet cherry cultivars averaged over seven years (2014-2020).

Cultivar	Peduncle length (cm)	Peduncle thickness (mm)	Stone weight (g)	Total soluble solids (%)	pH	Titrable acidity (%)
Delamarka	3.40ab	1.00b	0.23b	14.20d	3.76a	0.09d
Adli	3.66a	1.12b	0.23b	16.93b	3.63b	1.15a
Shandiz	3.60a	1.01b	0.37a	16.63bc	3.55b	0.12d
Toos	2.43c	1.26ab	0.38a	17.13b	3.43c	1.06b
Siyah-e-Ghazvin	2.80cd	1.36ab	0.20b	15.81c	3.52bc	0.10d
Attar	3.10bc	1.54a	0.21b	19.87a	3.76a	0.62c

Means followed by the same letters in each column are not significantly different at 1% probability level.

Table 5. Comparison of the leaf traits of Attar with early sweet cherry cultivars averaged over seven years (2014-2020).

Cultivar	Leaf length (cm)	Leaf width (cm)	Leaf length/Leaf width (cm)	Petiole length (cm)
Delamarka	14.26a	6.53a	2.38a	4.73a
Adli	13.59ab	6.21ab	2.35a	4.44ab
Shandiz	13.21bc	6.06bc	2.19b	4.22b
Toos	13.15bc	6.01bc	2.18b	3.89c
Siah-e-ghazvin	12.38c	5.73cd	2.03c	3.23d
Attar	10.51d	5.52d	1.72d	3.14d

Means followed by the same letters in each column are not significantly different at 1% probability level.

et al. (2020) who indicated that leaf traits are important traits in sweet cherry breeding and cultivars are different for these charactristics.

Yield evaluation

One of the important traits in developing new cherry cultivars is the yield per unit area. The yield of the Attar cultivar compared to the early cultivars such as Adli, Shandiz, and Toos was higher at the peak of the economic fruiting stage with an average yield of 55 kg per tree (Table 6). High yield is one of the distinguishing features of this cultivar compared to the introduced early cultivars (Figure 5).

Table 6. Comparison of the yield of Attar with early sweet cherry cultivars averaged over seven years (2014-2020).

Cultivar	Yield (kg per tree)							
	2014	2015	2016	2017	2018	2019	2020	Average
Delamarka	10.4	10.7	12.0	13.6	13.0	20.0	17.6	13.9
Adli	8.7	10.0	12.7	13.4	14.0	13.7	14.0	11.7
Toos	8.0	11.5	10.8	12.5	12.0	12.0	13.5	11.5
Shandiz	13.0	14.0	13.6	18.8	19.7	20.0	25.7	17.84
Siyah-e-ghazvin	12.0	14.0	12.5	14.0	13.0	14.5	14.6	13.50
Attar	15.0	25.7	30.0	34.5	40.0	38.0	40.0	31.8
Siyah-e-Mashhad	11.0	13.5	15.0	17.0	18.7	20.5	24.0	15.1
Takdane	10.0	12.0	13.0	12.0	14.0	15.5	13.0	11.21

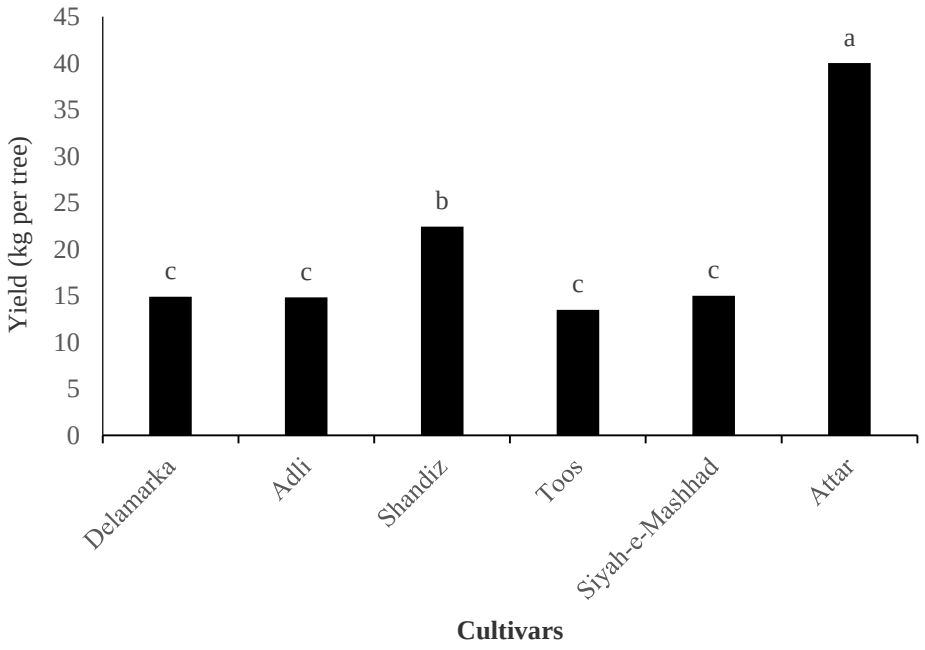

Figure 5. Comparison of the yield of Attar with early sweet cherry cultivars averaged over seven years (2014-2020).

Conclusion

Developing new cultivars with different maturity is one of the important goals of cherry breeding programs. After the introduction of the first very early cherry cultivar called Adli in 2015 and the introduction of two early cultivars in 2019 [i.e. Shandiz, which is one week later than the Adli cultivar (third week of May) and Toos, which can be harvested in the fourth week of May], the early-maturing Attar genotype with higher fruit weight, higher total soluble solids content, and precocity in the first week of June is proposed as a promising new cherry cultivar. Also, Attar had a higher yield at the peak of the economic fruiting stage compared with other early cultivars and can play an important role in increasing the income of cherry producers.

Conflict of interest

The authors declare that they have no conflict of interest with any organization concerning the subject of the manuscript.

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معرفی عطار رقم جدید گیلاس زودرس با کیفیت میوه مناسب

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چکیده

معرفی ارقام جدید گیلاس زودرس یکی از مهم‌ترین اهداف برنامه های پرورش گیلاس در ایران است. رقم عطار با اجرای هشت طرح تحقیقاتی به مدت ۲۱ سال از سال ۱۳۷۷ از ژرم پلاسم‌های گیلاس بومی خراسان رضوی انتخاب شد. ارزیابی ویژگی‌های رویشی، زایشی و پومولوژیکی ژنوتیپ‌ها به همراه سایر ارقام طی سال های ۱۳۸۴ تا ۱۳۹۹ منجر به معرفی رقم عطار شد. نتایج نشان داد که رقم عطار دارای عادت رشدی نیمه پراکنده و درجه شاخه‌دهی دهی متوسط است. زمان اولین گلدهی رقم عطار در هفته دوم فروردین ماه بود. مطالعه وضعیت گرده‌افشانی نشان داد که این رقم خود ناسازگار است. ارقام سیاه مشهد، سوئیت هارت و دوم رس مشهد گرده افشان مناسبی برای عطار بودند. زمان برداشت عطار در هفته اول خردادماه بود. میانگین وزن میوه رقم عطار (۷/۷۳ گرم) بیشتر از رقم شاندیز (۷/۲۳ گرم) و توس (۶/۸۷ گرم) بود. همچنین، کل مواد جامد محلول در عطار (۱۹/۸۷ درصد) بیشتر از رقم شاندیز (۱۶/۶۳ درصد) و توس (۱۷/۱۳ درصد) بود. عملکرد عطار در مرحله باردهی اقتصادی، ۴۰ کیلوگرم در هر درخت بود که از رقم شاندیز (۲۲/۴۳ کیلوگرم) بالاتر بود. اختلال ترک خوردگی میوه در رقم عطار کمتر از سایر ارقام بود. عطار ارزش اقتصادی بالایی دارد و از این رو معرفی این رقم گیلاس می‌تواند نقش مهمی در افزایش درآمد تولیدکنندگان گیلاس داشته باشد.

واژه‌های کلیدی: رقم؛ صفات فنولوژیکی و پومولوژیک؛ عطار؛ عملکرد؛ گیلاس