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Biochemical, Mineral, and Enzymatic Properties of Date Fruits (Barhee and Piyarom Cultivars) as Influenced by Different Pollen Sources

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ABSTRACT

The present study investigated the effects of five Iranian male palm pollen grains as pollen sources on the fruit quality of two cultivars, 'Barhee' and 'Piyarom' (offshoot-derived and tissue culture-derived). The biochemical and enzymatic properties of fruit dates at the Tamar stage (full maturity) enabled the evaluation of pollen source effects on fruit quality. The research location was Jahrom Research Station, Fars Province, Iran, from 2018 to 2019. The pollen sources were genotypes '7001' (control), '7005', '7013', '7030', and 'B11'. Pollinated with 7013 pollen, Offshoot-erived (OFS) trees of the 'Barhee' cultivar had the highest fruit flesh pH (7.07). In contrast, the lowest pH value (5.84) occurred in fruits of Tissue Culture-Derived (TCD) trees of the 'Piyarom' pollinated with the 7030. In the OFS 'Piyarom' the pollen source 7001 caused the highest fruit TSS (68.83%). When pollinated with the B11, 'Barhee' had the lowest fruit TSS (44.90%). In TCD 'Piyarom' trees, the 7030 pollen caused the highest TSS (62.53%). By receiving pollen from B11, the 'Barhee' produced fruits with the lowest TSS (44.23%). Regardless of being OFS or TCD and of the pollen source, on average, 'Barhee' produced fruits with more moisture content than fruits of the 'Piyarom'. In OFS 'Piyarom' trees, pollen from the 7030 caused the highest Fruit Dry Matter (FDM) (87.40%), whereas the 'Barhee' pollinated with the 7001 produced fruits with the lowest FDM (67.15%). In TCD 'Piyarom' palms, pollen from the 7030 caused the highest FDM (85.19%), compared to the 'Barhee' pollinated with the 7013, which showed the lowest FDM (67.87%). Pollen from the 7030 caused the highest total sugar content in the fruits of OFS and TCD 'Piyarom' trees. The fruits of OFS 'Piyarom' trees had more Fe and Polyphenol Oxidase (PPO) activity than TCD 'Piyarom' trees.

Keywords: Artificial pollination, Fruit quality, Pollen germination, *Phoenix dactylifera* L.

INTRODUCTION

The date palm (*Phoenix dactylifera* L.) from Arecaceae family, is one of the most valuable fruits in tropical regions due to its high economic and nutritional importance. The date palm as a dioecious plant generates male and female flowers separately on the individual trees (Abeed *et al.,* 2020). In 2020, total date fruit production in the world amounted to about 13.5 million tons, of which Iran produced 1.3 M.t of dates, accounting for almost 10% of the world's total production (FAO, 2020). 'Barhee' and 'Piyarom' cultivars are among the best commercial cultivars of date palm in Iran, where agriculture experts propagate them via tissue culture to overcome the limitations of offshoot propagation (Zargari *et al.,* 2021). In some cases, however, Tissue

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Culture-Derived (TCD) 'Barhee' and 'Piyarom' plants grow abnormally and develop abnormal phenotypes due to somaclonal variation because of genetic and epigenetic changes during somatic embryogenesis. In several cases, low fruit yield has reportedly occurred in TCD plants of the 'Barhee' cultivar (Zargari *et al.,* 2021).

Previous research considered pollen grains from different date palm cultivars and their effects on fruit properties. Pollen grains directly affect date fruit quality and quantity (Omaima *et al.,* 2014; Siyahsar *et al.,* 2018). The occurrence of low yields in some trees can be related to pollen viability (Giordani and Frri, 2014). Some genotypes serve as pollen sources and differ from each other in terms of pollen production, pollen grain size, and quality. This diversity emanates from their differences in genetic structure (Zaid and de Wet, 2002). Pollen grains directly affect the biochemical properties of the fruit (Shafique *et al.,* 2011), especially pH, TSS, and FTS characteristics (Heydari and Abbasi, 2011). Mustafa *et al.* (2014) showed that the biochemical properties of date fruit, such as organic acid, total soluble solids (TSS), and total sugars varied because of the type of pollen source. Iqbal *et al.* (2012) observed the effects of pollen on the yield and quality of date fruits regarding two cultivars 'Dhakki' and 'Zahidi.' They reported that the compatibility of pollen-stigma interactions significantly affected the fruit yield. Another research on the effects of pollen sources and the abundance of pollen grains on female trees of the 'Dhakki' cultivar showed that the type of pollen source, as a variable, had no significant effect on the fruit yield, but significantly affected several quality traits of the fruit (Shafique *et al.,* 2011).

The propagation of 'Barhee' and 'Piyarom' date cultivars via tissue culture techniques has recently increased in Iran. However, the resultant trees can sometimes become low-yielding because of suboptimal protocols in the tissue culture process. Unfortunately, no considerable morphological differences occur between Offshoot-derived (OFS) and Tissue Culture-Derived (TCD) plants in the vegetative stage, requiring trees to pass from the juvenile stage to maturity before researchers can detect their low-yielding disorder. The problem of low yield and fruit abnormalities of TCD trees was reported by other researchers (Awad, 2006; Bouhouche *et al*., 2006). Since it may create economic challenges for date palm growers, the current research aimed to evaluat the effects of different pollen sources on the fruit quality of OFS and TCD palm trees of 'Barhee' and 'Piyarom' cultivars in the Jahrom region of Iran. 'Barhee' and 'Piyarom' are commercial cultivars and produce high-quality marketable fruits for the export market.

MATERIALS AND METHODS

Plant Materials and Parameters

This study was conducted on date palm cultivars 'Barhee' and 'Piyarom' (Figure 1) in Jahrom Agricultural Research Station, situated at 1,070 meters above sea level (28° 28' 48" and longitude 53° 31' 20"). Female palm trees and male pollen sources had labels by placing plaques on the tree trunks, on February 2018. The labeling was to facilitate their selection and assist in future referrals. Experiment was done in factorial, with three factors in a randomized complete block design. Five genotypes as pollen sources included 7001 (control), 7005, 7013, 7030, and Boyer 11 (B11), the latter grew from tissue culture, and all others grew from offshoots. Morphological characteristics of male spathes described the studied genotypes (Figure 2). The pollinated female trees were cultivars of 'Barhee' and 'Piyarom' that originated from either tissue culture or offshoots. The variables had arrangements in three replications for two growing seasons (2018 to 2019). For each cultivar, 30 female palm trees (15 OFS and 15 TCD) entered the experiment. Each tree

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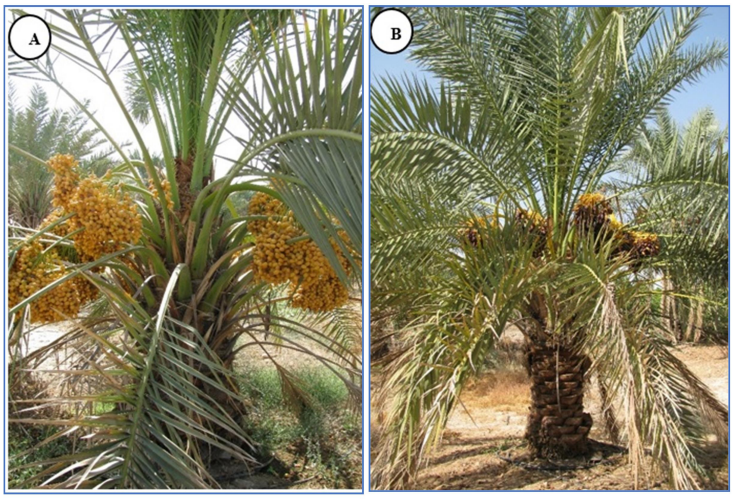

Figure 1. Female tree of TCD 'Barhee' (A) and OFS 'Piyarom' (B) at the Agricultural Research Station, Jahrom.

Figure 2. Male spathes of the pollen source (A), a male flower of genotype 7030 (B), and a male flower of genotype 7013 (C). Image at 10X magnification using a research microscope.

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was ten years old. A pollen germination test was done before collecting pollen from male flowers on the collected pollen grains and before using them for controlled artificial pollination. The female spathes received pollen, as described by Zargari *et al*. (2023). After sampling sixty fruits from the bunches of each tree at the Tamar (full maturity) stage, seven variables were evaluated, including fruit pH, Total Soluble Solids (TSS), fruit moisture, Fruit Dry Matter (FDM), and total sugar content. Also, the amount of iron was measured in the date fruit, as well as one enzyme (polyphenol oxidase). All measurements took place according to the standard descriptors of Differentiation, Uniformity, and Stability tests for dates (DUS).

Pollen Grains and Germination

With the pollen germination medium in distilled water, we added 10% sucrose, boric acid (150 ppm), and 2.5 g L^{-1} gerlite in Petri dishes and placed the solution in an incubator at 25 °C for 24 hours. Pollen germination was monitored under a microscope to estimate pollen germination percentage according to the following equation (Ismail, 2014).

$$PG= \frac{\text{Number of germinated pollen grains per field}}{\text{Total number of pollen grains per field}} \times 100$$

Where PG is Pollen germination.

Measurement of Fruit Quality Properties

TSS was measured using an ATAGO digital refractometer (Atago, Tokyo, Japan), and the results were expressed as °Brix (Jamil *et al.,* 2010). The digital pH meter measured pH values in date palm fruits (AOAC, 1990). The moisture content and dry matter of date palm fruits were determined according to the standard methods provided by the Association of Official Analytical Chemists (AOAC, 2005) and a relevant reference (Jamil *et al.,* 2010). Total sugar content was measured using an established method (Irigoyen *et al.,* 1992).

Measurement of Iron and Polyphenol Oxidase

About 1 g of powdered date fruit flesh was burned in a muffle furnace at 530°C for five hours to measure the iron content of date palm fruits. Then, the ash was dissolved in 5 mL hydrochloric acid (20%), with the resultant solution in a 50 mL volumetric flask. The final volume remained in distilled water. The iron content in the ash was analyzed separately using an atomic-absorption spectrophotometer (Fayadh and Al-Showiman, 1990).

The method involved measuring polyphenol oxidase activity by calculating the change in absorbance (420 nm) at 30°C in a reaction mixture containing 0.5 mL enzyme extract, 2.3 mL potassium phosphate buffer (pH 6.2), and catechol (0.2 mL, 0.2 M) as a buffer (Jiang *et al.,* 2002).

Statistical Analysis

SPSS ver. 23.0 statistical software checked the data for normality. Data analysis ran through SAS (9.3) software and a comparison of means operated on the Least Significant Difference (LSD) test ($P\leq 0.05$). Graphs illustrations were by Microsoft Excel (2016). Bartlett's test was used to examine the homogeneity of variances in maternal tissue culture-derived and offshoot-derived plants, revealing the general analysis of variance. According to the Chi-Square value and its significance level ($P\leq 0.05$), variances were homogeneous in all variables, and a combined analysis of variance was allowed.

RESULTS AND DISCUSSION

This study evaluated the effects of pollen source on date fruit quality of cultivars

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'Barhee' and 'Piyarom.' Previous reports indicated the role of pollen sources on yield and fruit set (Zargari *et al*., 2023). Pollen sources in the current research affected prominent fruit quality factors, and their effects mainly manifested during the postharvest period and date marketing.

In Vitro Germination of Pollen Grains

There was a significant difference between the germination percentages of various pollen grains from different pollen sources used (P≤ 0.01). The comparison of mean values for pollen germination (%) (two-year statistics) showed that pollen from genotype 7013 had the highest germination percentage (92.93%), which differed significantly from the germination percentage of other pollen. Pollen from genotypes 7030 and 7005 were almost identical in their germination (77.75 and 74.67%, respectively). The germination percentage of TCD B11 pollen (38.75%) was the lowest compared to all other genotypes (Figure 3).

One of the most significant factors in successful pollination is the viability of pollen grains. Since it directly affects the total fruit yield of palm trees (Munir *et al.,* 2020), low tree yield can sometimes result from the insufficient viability of pollen grains (Giordani and Ferri, 2014). Thus, selections of effective pollen sources aimed at the viability of their pollen grains to create optimal yields in the 'Barhee' and 'Piyarom' cultivars. In this study, the minimum germination of applied pollen grains was more than 38%, contributing significantly to high yields in 'Barhee' and 'Piyarom'.

Biochemical Properties of Date Palm Fruit (DPF)

pH of DPF

The 'Barhee' cultivar OFS produced fruits with the highest pH by receiving pollen from pollen source 7013 (7.07), compared to pollen source 7001 (6.75). In TCD 'Barhee' trees, the highest fruit pH occurred when receiving pollen from the pollen source 7013, whereas the lowest pH (5.84) occurred in 'Piyarom' fruits by receiving pollen from 7030. Accordingly, 'Barhee' fruits had the highest pH value when using 7013 and 7030 (Table 1).

In this study, the fruit flesh pH varied from 5.95 to 6.98. The pollen source 7013 caused the highest pH in fruits of the TCD and OFS trees, and 7013 was superior to other pollen sources because of the genetic structure of its pollen. The type of pollen can

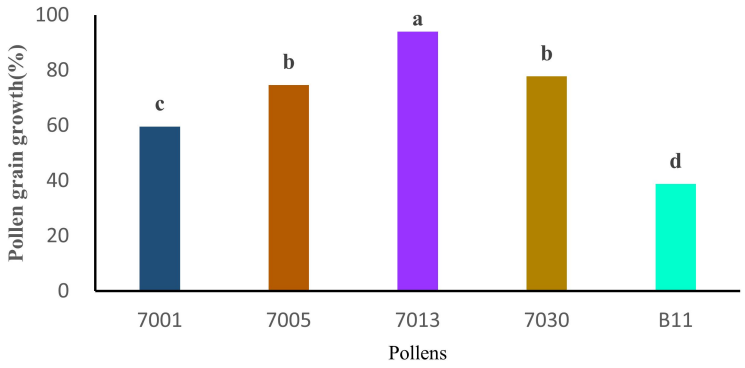

Figure 3. Comparison among two-year statistics of mean values regarding pollen germination, showing dissimilar letters that indicate a significant difference (P≤ 0.05) according to the LSD test.

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Table 1. Effect of pollen source on fruit flesh pH.[a]

Cultivars	Pollens	PH		
		Offshoot	Tissue culture	Average
Barhee	7001	6.75^{ab}	6.12^{cd}	6.43^{c}
	7005	6.60^{bc}	6.38^{bc}	6.49^{bc}
	7013	7.07^{a}	6.88^{a}	6.98^{a}
	7030	6.91^{ab}	6.65^{ab}	6.78^{ab}
	B11	6.17 ^{de}	5.88^{d}	6.03^{d}
Piyarom	7001	6.57^{bcd}	6.21^{bcd}	6.39^{c}
	7005	6.00^{e}	5.93^{cd}	5.97^{d}
	7013	6.19^{cde}	6.24^{bcd}	6.22^{cd}
	7030	6.31^{cde}	5.84^{d}	6.08^{d}
	B11	5.90^{e}	6.01^{cd}	5.95^{d}

[a] (a-e): In each column, mean values with similar letters are not significantly different (P≤ 0.05) according to the LSD test.

significantly affect fruit pH (Zargari, 2021; Heydari and Abbasi, 2011). Similarly, Siyahsar *et al.* (2018) evaluated the effects of three pollen sources on the quantitative and qualitative characteristics of date fruits harvested from the TCD 'Zahedi' cultivar. They stated that the pollen source and fruit growth stage affected fruit flesh pH. A relevant study evaluated how pollen affected date fruits of the 'Shahani' cultivar, showing that the pollen sources significantly affected the pH of date fruit flesh (Khajehpour-Tadvani *et al.,* 2016), which confirmed the current results.

Total Soluble Solids (TSS)

The effects of pollen source on the pollination of TCD and OFS flowers showed that the highest TSS occurred in 'Piyarom' fruits (62.53%), pollinated with genotype 7030, compared to the 'Barhee' (45.57%). The lowest TSS occurred in the 'Barhee', pollinated with B11 and 7005 (44.23 and 44.78%, respectively), compared to pollination with genotype 7001 (45.57%) (Table 2). The highest TSS in the fruits of OFS trees occurred in 'Barhee' (68.93%), pollinated with 7013, followed by 'Piyarom' (62.28%), pollinated with 7013. The lowest TSS in the fruits of 'Barhee' was caused by pollen B11 (44.90%), followed by 7005 (45.03%), compared to the pollen of 7001 (46.10%) on 'Barhee.' The results indicated that pollen sources 7030 and 7013 caused higher TSS content in fruits, compared to the effect of other pollen sources in this research (Table 2), probably because of the high pollen viability in these genotypes.

Although TSS increased during the ripening stage, primarily because of moisture loss from the fruit and the conversion of insoluble solids into soluble compounds (Afshari Joybari and Farhanaki, 2011), the pollen sources affected the TSS differently in this study. This variation probably resulted from the biosynthesis of fructose and sucrose in the fruits (Fukuoka, 2009). Shafique *et al.* (2011) reported that the type of pollen is a valuable indicator of TSS. In a relevant study, four types of pollen fertilized 'Barhee' and showed significant differences in affecting the TSS (Abd Elhalim, 2020).

Fruit Moisture (FM) and Fruit Dry Matter (FDM)

In TCD and OFS trees, the pollen source affected the moisture content and dry matter of date fruits, which was suitable for comparison by the LSD test (P≤ 0.05) (Table 3). The results showed that the highest percentage of FM (32.85%) occurred in OFS 'Barhee' trees, pollinated with 7001, which did not differ significantly from the effects of other pollen sources. The OFS 'Piyarom', pollinated with 7030, had the

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Table 2. TSS of date fruits 'Barhee' and 'Piyarom' cultivars produced from various pollen sources.[a]

Cultivars	Pollens	TSS (%)		
		Offshoot	Tissue culture	Average
Barhee	7001	46.10^{d}	45.57^{ef}	45.83^{ef}
	7005	45.03^{d}	44.78^{ef}	44.91^{f}
	7013	47.03^{d}	45.52^{ef}	46.28^{ef}
	7030	48.36^{cd}	47.07^{e}	47.71^{e}
	B11	44.90^{d}	44.23^{f}	44.57^{f}
Piyarom	7001	68.93^{a}	53.33^{c}	61.13^{b}
	7005	59.15^{b}	51.33^{cd}	55.24^{c}
	7013	68.28^{a}	59.56^{b}	63.92^{a}
	7030	65.60^{a}	62.53^{a}	64.07^{a}
	B11	52.48^{c}	50.67^{d}	51.58^{d}

[a] (a-f): In each column, mean values with similar letters are not significantly different ($P \leq 0.05$) according to the LSD test.

lowest percentage of FM (12.60%). The TCD of 'Barhee', pollinated with 7013 and 7005, had the highest FM (32.13 and 32.08%, respectively) compared to the TCD of 'Piyarom' (20.43%) (Table 3).

The OFS 'Piyarom' pollinated with 7030, B11, and 7005 had a higher FDM than the OFS 'Barhee' (67.15%). The TCD 'Piyarom' pollinated with 7030, B11, 7005, and 7013, had the highest percentage of FDM, whereas the lowest occurred in the TCD 'Barhee,' pollinated with 7013 and 7005 (68.87 and 67.92%, respectively). When pollinated with 7030 and B11, 'Piyarom' had the highest percentage of FDM (Table 3).

The moisture content of fruits is one of the essential factors in horticultural marketing, because of its direct effect on fruit quality and preservation. The amount of FM depends on the fruiting stage and is crucial in determining storage conditions. In this research, the fruit moisture varied from 12.60% to 32.85%, as pollen sources 7001, 7005, and 7013 showed higher metaxenia effects than others. Previous reports indicated that pollen grains affect the percentage of FM, so pollen grain types

Table 3. Effect of pollen source on moisture content and dry matter of date fruits in cultivars 'Barhee' and 'Piyarom'.

Cultivars	Pollens	FM (%)			FDM (%)		
		Offshoot	Tissue culture	Average	Offshoot	Tissue culture	Average
Barhee	7001	32.85^{a}	31.95^{a}	32.40^{a}	67.15 ^{c}	68.05 ^{c}	67.60 ^{d}
	7005	32.34^{a}	32.08^{a}	32.21^{a}	67.66 ^{c}	67.92 ^{c}	67.79 ^{d}
	7013	32.07^{a}	32.13^{a}	32.10^{a}	67.93 ^{c}	67.87 ^{c}	67.90 ^{d}
	7030	31.81^{a}	31.92^{a}	31.86^{a}	68.19 ^{c}	68.08 ^{c}	68.14 ^{d}
	B11	30.83^{a}	30.38^{a}	30.61^{a}	69.17 ^{c}	69.62 ^{c}	69.39 ^{d}
Piyarom	7001	30.13^{a}	20.43^{b}	69.87^{c}	69.87 ^{c}	79.57 ^{b}	74.72 ^{c}
	7005	16.73^{c}	16.00^{c}	83.27^{a}	83.27 ^{a}	84.00 ^{a}	83.63 ^{a}
	7013	23.13^{b}	16.32^{c}	76.87^{b}	76.87 ^{b}	83.68 ^{a}	80.27 ^{b}
	7030	12.60^{c}	14.81^{c}	87.40^{a}	87.40 ^{a}	85.19 ^{a}	86.30 ^{a}
	B11	15.73^{c}	15.27^{c}	84.20^{a}	84.20 ^{a}	84.73 ^{a}	84.47 ^{a}

[a] (a-d): In each column, mean values with similar letters are not significantly different ($P \leq 0.05$) according to the LSD test.

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showed metaxenia effects on the FM percentage of 'Barhee' (Omar *et al.,* 2014; Abeed *et al.,* 2020). The results of this study on FM are consistent with previously reported studies (Omar *et al.,* 2015; Salomon-Torres et al., 2017). The results indicated that genotype 7030 caused the highest percentage of FDM, and the pollen source 7030 caused a higher metaxenia effect on FDM than other pollen sources. The genetic structure of pollen from pollen source 7030 was more compatible with the recipient cultivar. One of the significant indicators in marketing date palm fruit is the amount of FDM based on the preference of customers, as higher FDM not only increases the quality of date palm fruit but can also increase the postharvest shelf life (Burdon *et al.,* 2004; Seyrek *et al.,* 2017).

Fruit Total Sugar (FTS)

In TCD and OFS trees, the effect of pollen sources on the sugar content of date fruits was comparable according to the LSD test (P≤ 0.05). The OFS 'Piyarom', pollinated with the 7030 and 7013, had the highest FTS (67.11% and 61.52%, respectively), and the lowest occurred in the TCD 'Piyarom', pollinated with B11 (49%), compared to pollination with the 7001 (52.07%). Moreover, the fruits of TCD 'Piyarom', pollinated with the 7030, had the highest FTS (70.97%). The lowest FTS was found in the TCD 'Piyarom' (46.50%), whereas the OFS 'Piyarom' trees had higher FTS values when pollinated with the 7030 and 7013 (Table 4).

In this study, 'Piyarom' and 'Barhee' cultivars ranked first and second regarding FTS, respectively. The FTS depends on the pollen source. According to Table 4, the fruits of the OFS palm dates had a higher FTS than the TCD ones. Furthermore, pollination with the 7030 and 7013 caused higher FTS values due to the metaxenia effect. Pollen grains usually affect the activity of hydrolytic enzymes, such as polygalacturonase, in the dissolution of pectin and cellulase in date fruit and increase the FTS. Salomon-Torres *et al.* (2017) evaluated the effects of five types of pollen grains on the FTS of the 'Medjool' cultivar, and reported that pollen from the 'Khadrawi' cultivar caused the highest FTS. Previous studies have also shown that the effect of pollen grains on FTS depends on the genotype of the pollen source and the female tree (Heydari and Abbasi, 2011). Several other studies reported similarly, such as Farag *et al.* (2012), Mustafa *et al.* (2014), and Siyahsar *et al.* (2018).

Table 4. Effect of pollen source on total sugar content in date fruits of cultivars 'Barhee' and 'Piyarom'.[a]

Cultivars	Pollens	FTS (%)		
		Offshoot	Tissue culture	Average
Barhee	7001	53.52 ^{cde}	54.00^{bcd}	53.76^{cd}
	7005	50.23^{e}	50.47^{cde}	50.35^{de}
	7013	56.14^{cd}	56.13^{bc}	56.14^{bc}
	7030	58.42^{bc}	58.00^{b}	58.21^{b}
	B11	51.48^{de}	50.33^{cde}	50.91^{de}
Piyarom	7001	52.07^{de}	46.50^{e}	49.29^{e}
	7005	50.13^{e}	50.15^{de}	50.14^{de}
	7013	61.52^{b}	57.45^{b}	59.49^{b}
	7030	67.17^{a}	70.97^{a}	69.07^{a}
	B11	49.00^{e}	50.03^{de}	49.52^{e}

[a] (a-e): In each column, mean values with similar letters are not significantly different (P≤ 0.05) according to the LSD test.

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Iron (Fe) Content of Fruit Flesh

The results showed that the fruits of OFS in 'Piyarom' had the highest Fe content when pollinated with the 7030 and 7013 (1.87 and 1.82), respectively (Table 5). The fruits of TCD trees ('Piyarom' cultivar) with pollen genotypes 7030 and 7013 had the highest Fe content (1.87 and 1.73 mg 100 g^{-1}, respectively) compared to the TCD 'Barhee' (0.47 mg/100g). Moreover, the lowest Fe content occurred in the fruits of TCD 'Barhee,' regardless of pollen source (Table 5). When pollinated with the 7030, fruits of the 'Piyarom' had the highest Fe content, whereas the lowest occurred by the pollen source 7005 (Table 5).

When genotype 7030 pollinated the 'Piyarom' flowers, the fruits had the highest Fe content. In this regard, the pollen sources 7030 and then 7013 were superior to the others. The fruits of OFS trees had more Fe content than those of TCD trees, which showed that the genetic structure of pollen, the maternal plant source, and the female cultivar affected the Fe content. Fe is an essential trace element, and varied from 1.83 to 0.44 mg 100 g^{-1} in the current study. Although dates contain trace amounts of Fe, they are a good source (1.14-7.57 mg 100 g^{-1}) compared to other fruits (Ghafoor *et al.,* 2017). Habib and Ibarheem (2011) investigated 18 date cultivars in the United Arab Emirates, reporting that the Fe content varied from 0.67 to 1.75 mg 100 g^{-1}.

Polyphenol Oxidase (PPO) Enzyme Activity

Using pollen sources 7001 and OFS of 'Piyarom' trees, the highest PPO activity occurred in the fruits (2.47%), whereas the lowest occurred in the OFS 'Barhee' when pollinated with genotype 7013 (0.83%). In TCD trees, the highest PPO activity (2.27%) occurred by the pollen source 7001 on 'Piyarom' trees, compared to the other pollen sources. Furthermore, the lowest PPO activity occurred in fruits of the TCD 'Barhee', pollinated with B11 and 7005 (0.93%) (Table 6).

On average, PPO activity was higher in fruits of 'Piyarom' than in 'Barhee.' The lowest PPO activity occurred in fruits of 'Barhee'. Fruits of 'Piyarom' appeared darker than those of 'Barhee' because of the higher PPO, which caused non-oxidative browning in the dates. Previous research indicated that PPO reactions spoil at least 50% of tropical fruits, causing biochemical changes in tannins (Fennema, 2008). The reactions cause a loss of astringent taste in dates and cause non-oxidative browning (Saleem *et al.,* 2005). Brandelli and Lopes

Table 5. Effect of pollen source on Fe content of date fruits in cultivars 'Barhee' and 'Piyarom'.[a]

Cultivars	Pollens	Fe (mg 100 g^{-1})		
		Offshoot	Tissue culture	Average
Barhee	7001	0.47^{c}	0.47^{c}	0.47^{d}
	7005	0.42^{c}	0.46^{c}	0.44^{d}
	7013	0.46^{c}	0.46^{c}	0.46^{d}
	7030	0.48^{c}	0.47^{c}	0.48^{d}
	B11	0.46^{c}	0.44^{c}	0.45^{d}
Piyarom	7001	1.68^{b}	1.62^{b}	1.65^{c}
	7005	1.70^{b}	1.72^{ab}	1.71^{bc}
	7013	1.82^{ab}	1.73^{a}	1.78^{ab}
	7030	1.87^{a}	1.78^{a}	1.83^{a}
	B11	1.73^{ab}	1.70^{ab}	1.72^{bc}

[a] (a-d): In each column, mean values with similar letters are not significantly different (P≤ 0.05) according to the LSD test.

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Table 6. Effect of pollen source on polyphenol oxidase activity of date fruits in cultivars 'Barhee' and 'Piyarom'.[a]

Cultivars	Pollens	PPO (%)		
		Offshoot	Tissue culture	Average
Barhee	7001	1.33[c]	1.13[b]	1.23[c]
	7005	0.90[d]	0.93[b]	0.92[d]
	7013	0.83[d]	1.00[b]	0.92[d]
	7030	1.17[c]	1.07[b]	1.12[c]
	B11	0.83[d]	0.93[b]	0.88[d]
Piyarom	7001	2.47[a]	2.27[a]	2.37[a]
	7005	2.20[b]	2.20[a]	2.20[ab]
	7013	2.20[b]	2.13[a]	2.17[b]
	7030	2.20[b]	2.07[a]	2.13[b]
	B11	2.07[b]	2.13[a]	2.10[b]

[a] (a-d): In each column, mean values with similar letters are not significantly different ($P \leq 0.05$) according to the LSD test.

(2004) showed that the PPO activity increased gradually during the growth and development of peach fruits but showed a sharp decrease when the fruits matured.

CONCLUSIONS

Since pollen sources have a vital role in the quality of date palm fruits, choosing a proper pollen source is crucial to improve fruit yield and quality. Previous research indicated the effect of pollen sources on date fruit yield (Zargari *et al*., 2023). Here, this report reflected the qualitative indices of date palm fruits of 'Barhee' and 'Piyarom' cultivars, as affected by the type of pollen. Based on the metaxenia effect, pollen grains of various pollen sources affected fruit quality significantly and differently. Pollen sources 7013 and 7030 resulted in the best pH, TSS, FM, FDM, and FTS. Pollen source 7001 was in the same statistical group regarding its effects on FM and TSS. The OFS trees had a higher percentage of pH, TSS, FM, Fe, and PPO, whereas the TCD trees showed more FDM and FTS, but with a lower yield than the OFS trees. The highest Fe and PPO occurred in fruits of 'Piyarom' cultivar. These results indicated that the metaxenia effects of pollen sources acted differently on 'Barhee' and 'Piyarom' female cultivars.

Pollen from genotypes 7013 and 7030 showed the highest germination, whereas pollen from genotype B11 had the lowest germination. Ultimately, genotypes 7013 and 7030 are optimal pollen sources for obtaining high-quality dates in TCD and OFS 'Barhee' and 'Piyarom' cultivars.

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ویژگی‌های بیوشیمیایی، معدنی و آنزیمی میوه خرما (ارقام برحی و پیارم) تحت تأثیر منابع مختلف گرده

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چکیده

پژوهش حاضر با هدف بررسی تأثیر پنج دانه گرده نخل نر ایرانی به عنوان منابع گرده بر کیفیت میوه دو رقم برحی و پیارم (کشت بافت و پاجوش) انجام شد. ویژگی¬های بیوشیمیایی و آنزیمی میوه خرما در مرحله تمار امکان ارزیابی اثرات منبع گرده بر کیفیت میوه را فراهم کرد. محل تحقیق، ایستگاه تحقیقاتی جهرم، فارس، ایران از سال ۱۳۹۷ تا ۱۳۹۸ بوده است. منابع گرده ۷۰۰۱ (شاهد)، ۷۰۰۵، ۷۰۱۳، ۷۰۳۰ و B11 بودند. درختان پاجوشی (OFS) رقم برحی گرده¬افشانی شده با گرده ۷۰۱۳ بالاترین pH میوه (۷/۰۷) را نشان دادند. در حالی که کمترین مقدار) ۵.۸٤pH (در میوه درختان حاصل از کشت بافت (TCD) رقم پیارم گرده¬افشانی شده با ۷۰۳۰ مشاهده شد. در پیارم (OFS) منبع گرده ۷۰۰۱ بیشترین TSS میوه (٦٨/٨٣ درصد) را نشان داد. رقم برحی گرده¬افشانی شده باB11 ، کمترین (TSS) میوه (٤٤/٩٠ در صد) را داشت. در درختان پیارم TCD، گرده ۷۰۳۰ بیشترین TSS (٦٢/٥٣) درصد را نشان داد. رقم برحی گرده¬افشانی شده با گرده B11 میوه¬هایی با کمترین TSS (٤٤/٢٣ درصد) تولید کرد. رقم برحی صرف نظر ازOFS یا TCD و منبع گرده، به طور متوسط میوه هایی با رطوبت بیشتری نسبت به میوه های رقم پیارم تولید کردند. در درختان پیارمOFS ، گرده ۷۰۳۰ بیشترین ماده خشک میوه FDM (٨٧/٤٠ درصد) را نشان داد، در حالی که در رقم برحی با گرده¬افشانی ۷۰۰۱، میوه¬هایی با کمترین FDM (٦٧/١٥ درصد) تولید کرد. در درختان پیارم TCD ، گرده ۷۰۳۰ بیشترین FDM (٨٥/١٩ درصد) را تولید کرد. رقم برحی، گرده¬افشانی شده با ۷۰۱۳، کمترینFDM (٦٧/٨٧ درصد) را نشان داد. بیشترین میزان قند کل در میوه درختان پیارم OFS و TCD گرده¬افشانی شده با گرده ۷۰۳۰ مشاهده شد. میوه درختان پیارمOFS، آهن و پلی¬فنل¬اکسیداز (PPO) بیشتری نسبت به درختان پیارم TCD نشان دادند.

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