Pollen Sources Influence the Traits of Seed and Seed Oil in *Paeonia ostii* ‘Feng Dan’

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Abstract. The effects of different pollen sources on fruit and seed characteristics of *Paeonia ostii* ‘Feng Dan’ were investigated using analysis of three different pollination treatments and pollen sources from fifteen cultivars in two successive years. The results showed that self-pollination decreased fruit setting, the number of seeds per fruit, seed volume, seed and kernel weights, and the linoleic acid (LA) concentration in the seed oil, but increased the concentration of oleic acid (OA) compared with cross-pollination. Among those pollen donors, *P. suffruticosa* ‘Yinhong Qiaodui’ produced the highest fruit set (87.5%); the lowest fruit set was obtained with *P. suffruticosa* ‘Mo Run Jue Lun’ (44.33%). The most seeds per fruit were achieved by *P. suffruticosa* ‘Mochi Jin Hui’. *P. suffruticosa* ‘Dahong Baozhu’ produced the largest fruit, which contained larger and heaviest seeds. The oil extraction ratio (26% to 31.6%) and the concentration of three major unsaturated fatty acids (UFAs) in seed oil also significantly differed among pollen sources. The content of OA, LA, and α -linolenic acid (ALA) ranged from 13.82 to 24.79, 12.09 to 21.84, and 23.50 to 38.64 g/100 g crude oil, respectively. Overall, pollen source has clear effects on seed yield and even on fatty acid (FA) composition of seed oil in tree peony.

Tree peony (a woody shrub of family Paeoniaceae, genus *Paeonia*, and section *Moutan*) is native to China (Wister, 1962). It has been planted for more than 1600 years in China and has been introduced to Japan, America, and Europe since the Tang Dynasty (A.D. 618–907) (Li, 1998). At present, $\approx$ 2000 tree peony cultivars have been bred in China and are mainly divided into four geographical groups including the Northwest, Zhongyuan, Jiangnan, and Southwest groups (Zhang et al., 2007). According to preliminary statistics, the cultivated area of tree peony in China exceeds 20,267 ha (Li et al., 2015). Recently, *Paeonia ostii* ‘Feng Dan’ was promoted for planting for its seeds, which are characterized by abundant UFAs (>90%), mainly ALA followed by LA and OA (Zhang et al., 2016). Therefore, increased attention should be paid to increasing yield and quality during the expansion of the tree peony industry.

P. ostii ‘Feng Dan’ is a cross-pollinated plant without apomixes, and the seed setting of self-pollination is significantly lower than that of cross-pollination (Xin et al., 2014).

The breeding system of tree peony has also been examined in several wild species, such as *P. jishanensis* (Zhou et al., 1999) and *P. delavayi* (Li et al., 2014). However, there is a lack of information about the influence of different pollination treatments on seed weight, oil content, and FA composition.

As is commonly known, pollen sources have a direct influence on fruit and seed features of the maternal plant (Darwin, 1868; Focke, 1881). Effects of pollen sources on the quality and quantity of fruits and seeds have been reported in different plant species for many years (Denney, 1992; Swingle, 1928). In hazelnuts, the effects of self- and cross-pollination were observed (Fattahi et al., 2014). In date palms, Rezazadeh et al. (2013) reported that pollen source has the potential to modify and improve date production. In almonds, different pollination treatments affected oil content and composition, as well as nut and kernel weight (Kodad and Company, 2008). Increased seed setting rates in *P. ostii* ‘Feng Dan’ were reported by pollinating with pollen from different cultivars, according to Han et al. (2014). Nevertheless, the effects of different pollen sources on the characteristics of fruits and seeds have been neglected in tree peony.

The purpose of this study was to investigate the effects of different pollination treatments and pollen sources on the fruit and seed traits of *P. ostii* ‘Feng Dan’ and on its seed oil traits. Furthermore, this investigation will also provide reliable knowledge for well-organized tree peony plantations.

Plant materials and pollination. This study was conducted in two successive years (2015 and 2016) at the research institute of the Landscape Architecture Department, Northwest Agriculture & Forestry University, Yangling, Shaanxi province, China. The flowering times of 55 cultivars were recorded, and their pollen viability was investigated by the method of in vitro germination (Shivanna and Heslop-Harrison, 1981) in 2015. Finally, 15 cultivars that had high pollen germination rates (more than 30%) and similar flowering dates to those of *P. ostii* ‘Feng Dan’ were selected as pollen donors (Table 1).

The effects of different pollination treatments on the fruit and seed traits of *P. ostii* ‘Feng Dan’ were investigated by applying cross-, open-, and self-pollination on field-grown plants. Five uniform 8-year-old trees were selected, and in each tree, four flowers were selected for each pollination treatment. For the self-pollination group, 20 flowers were self-pollinated by hand and covered with waxed paper bags. For the open-pollination group, flowers were left without cover. For the cross-pollination group, the selected flowers were emasculated using forceps $\approx$ 3 d before blooming and covered with waxed paper bags. These flowers were regularly checked for the appearance of a bead of moisture on the stigma, indicating that the female parts had attained peak receptivity. As soon as emasculated flowers reached peak receptivity, dried pollen, which had been collected from another tree of the same population and stored earlier, was applied to the stigmas. After pollination, all of the pollinated flowers were again bagged to avoid contamination by other pollen and tagged. The bags were removed after 10 d.

The significance of pollen sources for the fruit and seed traits of *P. ostii* ‘Feng Dan’ was evaluated by pollinating with pollen from different tree peony cultivars under field conditions. Pollen was collected from selected pollen donors when the first flowers began to dehisce and dried on paper at room temperature. The pollination method was the same as that applied in the cross-pollination group in the pollination treatment experiment.

Measurements and data collection. Two months after pollination, the percentage of fruit set was counted for each combination. Fruit were harvested on 1 Aug. The diameter of each fruit was measured with digital calipers. Then, seeds were extracted from mature fruits, and the number of seeds was counted. Fifty seeds per combination were randomly selected and measured for volume and weight. Seeds were prepared from five individual pods and dried at 60 °C in an oven for 48 h to a constant weight. Then, the seedcoats were removed, and the kernel weight was measured.

The kernels were ground into small pieces and sieved (40 mesh). The extraction of seed oil was performed on a supercritical CO₂

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extraction apparatus (SFE-2 model; Applied Separations, Allentown, PA). Samples (10 g) of grounded peony kernel were placed into the extraction vessel. The extraction conditions were as follows: extraction time, static extraction for 30 min followed by dynamic extraction for 2 h; temperature, 45 °C; pressure, 300 bar; and flow rate of carbon dioxide (gaseous fluid), 30 L/h. The extracts were collected in a glass vial (50 mL). When the designated time was reached, the extraction vessel was depressurized, and the obtained oil was used for the following tests. The amount of extracted oil was gravimetrically determined after collection, and the extraction yield was expressed as the percent ratio of the mass of extracted oil to the mass of peony seed loaded into the extraction vessel, as follows:

$$\text{Extraction yield of seed oil (\%)} = \frac{\text{mass of extracted oil}}{\text{mass of dried material}} \times 100$$

Seed oil (0.2 g) was added into a capped glass vial (20 mL) and mixed with 4 mL of a methanol solution containing 2% sodium hydroxide. Then, the vial was placed in a water bath at 60 °C for 30 min. After reaction, the mixture was allowed to cool to room temperature and was treated with 2 mL of a boron trifluoride-methanol solution at a concentration of 14% wt. The vial was then heated in a 60 °C water bath for another 10 min. The mixture was mixed with 2 mL of *n*-hexane and vigorously shaken, then brought to room temperature. Next, 2 mL of saturated sodium chloride was added. After standing for 5 min, the organic phase was separated. Then, 500 µL of supernatant was transferred to a 2 mL vial and capped with a plastic cap having a polytetrafluoroethylene septum. In addition, 150 µL of tridecane acid methyl ester (10.0 mg·mL⁻¹ in *n*-hexane) was added as the internal standard for this work via a 200 µL pipette. After filtering, the solution was analyzed by gas chromatography–mass spectrometry.

The analysis of FAs was carried out by using a Thermo TRACE 1310 GC-ISQ and Thermo Scientific TriPlus RSH robotic sampler. A TG-WaxMS (30 m × 0.25 mm internal diameter, 0.25 µm film thickness; Thermo Fisher Scientific, Waltham, MA) capillary column was used in the experiment with helium as the carrier gas. The column temperature was initially 80 °C, was held for 1 min, then increased to 175 °C at 50 °C/min, was held for 1 min, and was finally increased to 210 °C at 3 °C/min (held for 5 min). Ultrahigh purity helium was used as the carrier gas at a flow rate of 1.0 mL/min. The temperatures of the ion source and transfer line were 280 and 250 °C, respectively, whereas the injector temperature was set at 250 °C for split injection at a split ratio of 20:1. The inject volume was 1 µL. The mass spectrometer was operated in positive ion mode with ionization energy of 70 eV and the scan range from 30 to 450 amu.

The oil components were identified by comparing their retention times with external standards and a mass spectra database search

(NIST05 Library). Five major FA methyl esters in each sample were quantified using an internal standard method. A standard curve was derived from the total ionic chromatogram of different concentration standards, where the x-coordinates and y-coordinates represent the concentration ratio and peak area ratio of external and internal standards, respectively.

Data analysis. Statistical analysis was performed using SPSS version 18.0 (SPSS Inc., Chicago, IL). One-way analysis of variance was used to analyze the effect of different pollination treatments and pollen sources on the fruit set percentages, number of seeds per fruit, seed and kernel weights, oil extraction ratios, and quantity of five major FAs and total FA. Statistical differences at $P \leq 0.05$ were considered significant, and the means were compared using Duncan's multiple range test at 0.05.

Results

Breeding system experiment

The fruit set, number of seeds per fruit, and the characteristics of fruits, seeds, and oil, resulting from self-, cross-, and open-pollination of *P. ostii* 'Feng Dan', were measured and are presented in Table 2. Fruits and seeds produced by open-pollination were at the middle level between cross- and self-pollination for almost all of the studied characteristics. Cross-pollination resulted in significantly higher values of fruit set, seeds per fruit, seed volume, and 100-seed and kernel weights in comparison with self- and open-pollination. Cross-pollination and open-pollination resulted in low OA and high LA concentrations in seed oil, when compared with self-pollination. Despite this, the oil extraction ratio and the quantity of the main FAs were not significantly different.

Pollen source experiment

Fruit setting and number of seeds per fruit. According to the present results, fruit setting and number of seeds per fruit were significantly affected by different pollen sources. The results showed that the percentage of fruit set ranged between 44.33% and 87.50% (Fig. 1). 'Yinhong Qiaodui' produced the highest fruit set (87.50%), which was followed by 'Zi Ju' (86%) and 'Cong Zhong Xiao' (85%). On the other hand, 'Mo Run Jue Lun' and 'Gejin Zi' produced the lowest fruit set (44.33% and 55.83%, respectively).

The number of seeds per fruit was also affected by different pollen sources, ranging from 36.25 to 50.86 (Fig. 1). 'Mochi Jin Hui', 'Dahong Baozhu', and 'Hongxia Yingyue' produced more seeds per fruit (>45) than the other pollen sources. The fewest number of seeds per fruit was produced by 'Sai Huanghou', which was followed by 'Dao Jin'.

Phenotypic characteristics of fruit and seed

Significant differences were observed in seed volume, 100-seed weight and kernel weight among pollen sources (Fig. 2). Fruit

diameter ranged from 68.14 to 109.28 mm, with 'Dahong Baozhu', 'Mo Run Jue Lun', 'Binglingzi', and 'Mochi Jin Hui' being the largest (>92 mm) and 'Yinhong Qiaodui', 'Gejin Zi', and 'Sai Huanghou' being the smallest (<72 mm) (Fig. 2).

Seed volume significantly ($P < 0.01$) differed among pollen sources and ranged from 240 to 378.67 mm³. 'Xiang Yu', 'Dahong Baozhu', 'Gejin Zi', 'Cong Zhong Xiao', and 'Mochi Jin Hui' produced larger seed volumes (>350 mm³) than 'Caozhou Hong' and 'Dao Jin' (240 mm³) (Fig. 2). Hundred seed weight varied among pollen sources ($P < 0.05$) ranging from 18.69 to 28.1 g (Fig. 2). The 100-seed weights of 'Caozhou Hong' and 'Dao Jin' (<20 g) were less than those of 'Dahong Baozhu', 'Zi Ju', 'Cong Zhong Xiao', and 'Mochi Jin Hui' (>27.8 g). Kernel weight was also affected by different pollen sources ($P < 0.05$) and ranged from 0.11 to 0.19 g, with 'Mochi Jin Hui', 'Cong Zhong Xiao', 'Zi Ju', and 'Dahong Baozhu' (0.19 g) being heavier than 'Caozhou Hong', 'Mo Run Jue Lun', and 'Dao Jin' (<0.13 g) (Fig. 2).

Seed oil traits

Pollen source variation was significant ($P < 0.05$) for the oil extraction ratio (Fig. 3). The oil extraction ratio ranged from 26.0% to 31.6% with 'Caozhou Hong', 'Dahong Baozhu', 'Baixue Ta', and 'Binglingzi' being higher (>30%) than that of 'Mo Run Jue Lun', 'Mochi Jin Hui', 'Sai Huanghou', and 'Gejin Zi' (<27%).

The concentrations of palmitic acid (PA), OA, LA, ALA, and total FAs were significantly affected by different pollen sources (Table 3). The total content of the five major FAs was calculated, and the results showed that the highest content of FAs was observed in the seed oil produced by 'Mo Run Jue Lun' (86.21 g/100 g crude oil), whereas the lowest content was found in that produced by 'Xiang Yu' (53.07 g/100 g crude oil).

The amounts of PA and stearic acid (SA) were relatively lower than the other three UFAs. The concentration of PA ranged from 2.5 g/100 g crude oil ('Xiang Yu') to 3.82 g/100 g crude oil ('Dao Jin'), whereas that of SA ranged from 0.89 g/100 g ('Sai Huanghou')

Table 1. Fifteen cultivars used as pollen sources in this study.

Cultivar	Cultivar group	Flower color
Binglingzi	Zhongyuan	Purple
Baixue Ta	Zhongyuan	White
Caozhou Hong	Zhongyuan	Red
Cong Zhong Xiao	Zhongyuan	Pink
Dahong Baozhu	Zhongyuan	Red
Dao Jin	Japanese	Double-color
Gejin Zi	Zhongyuan	Purple
Hong Baoshi	Zhongyuan	Red
Hongxia Yingyue	Zhongyuan	Pink
Mochi Jin Hui	Zhongyuan	Black
Mo Run Jue Lun	Zhongyuan	Black
Sai Huanghou	Northwest	Black
Xiang Yu	Zhongyuan	White
Yinhong Qiaodui	Zhongyuan	Pink
Zi Ju	Zhongyuan	Purple

crude oil to 1.35 g/100 g crude oil ('Dao Jin'). The content of the other three UFAs significantly varied among the seed oil produced by different pollen sources ($P < 0.01$). The OA content ranged from 13.82 g/100 g crude oil ('Xiang Yu') to 24.79 g/100 g crude oil ('Dao Jin'). The LA content ranged from 12.09 g/100 g crude oil ('Sai Huanghou') to 21.48 g/100 g crude oil ('Mo Run Jue Lun'), and the ALA content ranged from 23.50 g/100 g crude oil ('Xiang Yu') to 38.64 g/100 g crude oil ('Dao Jin').

Seed oil yield per fruit for all pollen sources was estimated using the data on fruit setting, seeds per fruit, kernel weight, and the ratio of oil extraction. The oil content per fruit is of varying significance among pollen donors (Fig. 4), ranging from 0.71 g ('Dao Jin') to 2.24 g ('Dahong Baozhu').

Discussion

Pollination treatment effects. The breeding system plays a crucial role in determining

seed and oil yield. Our results showed a certain preference to cross-pollination in fruit setting and seed number per fruit, which were in accordance with the findings of other authors in *P. jishanensis* (Luo et al., 1998; Zhou et al., 1999) and *P. delavayi* (Li et al., 2014). The decrease in fruit setting and number of seeds per fruit from self-pollination could be explained by self-incompatibility (SI). The SI response comprises a self- and nonself-recognition process between pollen and pistil, which is followed by inhibiting the development of self-pollen tubes (Takayama and Isogai, 2005). Moreover, *P. ostii* 'Feng Dan' is partially self-compatible, with 29.50% of fruit set producing 31.66 seeds per fruit. The existence of partial self-compatibility is also very important for plants to reduce extinction vulnerability (Bond, 1995).

Open-pollination produced less fruit and seeds than cross-pollination. Because bees are considered to be responsible for successful pollination (Li et al., 2014; Sanchez-Lafuente and Valera, 1999), bee behavior

may have a great influence on pollination. Naturally, the activities of bees would be easily affected by environmental conditions (unfavorable weather and temperature) and the color of flowers (Koffi et al., 2013). In addition, pollen from self and crosses could germinate together in the same stigma. Each pollen type caused an opposite effect, which is another reason for the decrease in fruit and seed production by open-pollination.

The results also showed that the values of the studied physical traits of the fruits and seeds produced by self-pollination always remained at a lower level. Fruits harvested from cross-pollination are larger and contain more, larger, and heavier seeds than those from self-pollination. The decrease in seed and kernel weights when comparing self- with cross-pollination has been attributed to inbreeding depression effects (Oukabli et al., 2002; Torre-Grossa et al., 1994). Inbreeding depression is defined as the reduction in biological fitness in a given population as a result of inbreeding or breeding of related individuals. Similar results were found in almonds (Torre-Grossa et al., 1994), hazelnuts (Fattahi et al., 2014), and pecans (Marquard, 1988), where kernels from self-pollination were smaller and lighter than those from cross-pollination.

The contents of oil and five major FAs were also influenced by different pollination treatments. An increase in OA content and decrease in LA were observed in seed oil produced by self-pollination, which was in accordance with the findings of other authors in several almond cultivars (Kodad, 2008; Kodad et al., 2009) and *Jatropha curcas* L. (Samocha et al., 2014). However, whereas the opposite was also observed in some almond cultivars by Kodad et al. (2009), the mechanism for the impact of cross- and self-pollination on the concentrations of OA and LA is still unknown. The decrease of LA in the self-pollination treatment and its increase in the cross-pollination treatment may be explained by the negative correlation between the percentages of OA and LA (Abdallah et al., 1998). A high OA (monounsaturated fatty acid) to LA (an omega-6 polyunsaturated fat) ratio in self-pollinated kernels is desirable as it improves the stability of the fats against rancidity and increases the kernels' shelf life (Kodad, 2008).

Pollen source effects. Pollen, which was obtained from different cultivars, caused wide ranges of fruit setting and number of seeds per fruit in *P. ostii* 'Feng Dan'. This is in accordance with the results of a previous study (Xin et al., 2014). 'Yinhong Qiaodui' and 'Zi Ju' produced higher fruit setting than free-pollination, whereas more seeds per fruit were produced by 'Mochi Jin Hui'. Both the percentage of fruit setting and seed number per fruit produced by 'Dahong Baozhu' remained at high levels, which demonstrates that choosing suitable tree peony cultivars could enhance the diversity of color in a plantation while maintaining its seed yield. Effects of different pollens on fruit set or the number of seeds per fruit have been reported

Table 2. The effects of different pollination treatments on fruit set, seeds per fruit, fruit diameter, seed volume, 100-seed weight, kernel weights, oil extraction ratio, five main fatty acid, and total fatty acid contents (g/100 g crude oil).

Variable	Pollination treatment		
	Cross ^z	Self	Open
Fruit set (%)	91.65 a ^y	29.50 b	86.00 a
Seeds per fruit	55.45 a	31.66 b	48.95 a
Fruit diameter (mm)	93.21 a	82.26 a	89.81 a
Seed volume (mm ³)	303.33 a	230.00 b	300.00 a
Hundred-seed weight (g)	27.75 a	22.16 c	25.26 b
Kernel weight (g)	0.18 a	0.14 c	0.17 b
Oil extraction ratio (% dry wt)	31.36 a	30.62 a	30.96 a
Palmitic acid (g/100 g)	3.51 a	3.05 a	3.39 a
Stearic acid (g/100 g)	0.92 a	1.06 a	1.08 a
Oleic acid (g/100 g)	14.96 a	16.56 a	15.82 a
Linoleic acid (g/100 g)	18.20 a	14.79 b	15.71 ab
α -Linolenic acid (g/100 g)	27.37 a	27.27 a	27.48 a
Total fatty acid (g/100 g)	64.96 a	62.73 a	63.48 a

^zCross-pollination (xenogamy) treatment.

^yIn each row, the means followed by the same letters are not significantly different at a 5% level of probability.

Fig. 1. Effects of pollen sources on fruit set and seed number per fruit.

Fig. 2. Effects of pollen sources on fruit diameter, seed volume, 100-seed weight, and kernel weight.

in many fruit crops, such as blueberries (Gupton and Spiers, 1994), cherimoyas (Kahn et al., 1994), *Hylocereus polyrhizus* (Mizrahi et al., 2004), mandarins (Wallace and Lee, 1999), and *Olea europaea* L. (Farinelli et al., 2012). The differences in fruit setting and seed number per fruit could be explained by the growth of the pollen tube, the development of fertilized ovules (Hao et al., 2013), or metaxenia.

Significant differences were also found in the phenotypic traits of fruits and seeds as an effect of pollination with pollen grains from different cultivars. These results are in

agreement with the findings of other researchers, who reported that the physical traits of fruits and seeds were affected by different pollen sources in date palms (Rezazadeh et al., 2013) and lychees (Degani et al., 1995). Therefore, it is possible that the size and weight of seeds could be enhanced by different pollen donors. However, the reason why the physical traits of fruits and seeds were influenced by pollen genotype remains poorly understood. Swingle (1928) reported that endogenous phytohormones are responsible for the xenia, whereas Liu (2008) proposed that

the signal to trigger the xenia effect may be mRNAs.

Previous studies have described that oil content in rapeseed (Wang et al., 2010) and maize (Weingartner et al., 2004) could be affected by pollen source. Our results showed that oil extraction ratio varied among pollen sources, with 'Gejin Zi' (26.0%) as the lowest and 'Caozhou Hong' (31.6%) as the highest. When we estimated oil yield per fruit, certain differences were revealed (Fig. 4). The oil content per fruit when pollinated by 'Dahong Baozhu' was more than twice that when pollinated by 'Dao Jin'.

Fig. 3. Effects of pollen sources on the oil extraction ratio of seeds.

Table 3. The effects of pollen sources on fatty acid contents of seed oil (g/100 g crude oil).

Pollen source	Palmitic acid	Stearic acid	Oleic acid	Linoleic acid	α -Linolenic acid	Total fatty acid
Binglingzi	3.21 abc ^z	1.12 ab	16.78 cdef	16.43 c	32.03 cd	69.58 bcde
Baixue Ta	3.71 a	1.13 ab	20.21 bc	18.13 bc	34.11 bc	77.29 ab
Caozhou Hong	3.13 abc	0.97 ab	15.98 def	15.08 c	26.44 efg	61.59 efg
Cong Zhong Xiao	3.37 ab	1.04 ab	18.42 cde	17.80 bc	28.21 defg	68.85 bcde
Dahong Baozhu	3.61 ab	1.19 ab	16.98 cdef	16.36 c	28.19 defg	66.33 cdef
Dao Jin	3.82 a	1.35 a	24.79a	17.44 bc	38.64 a	86.04 a
Gejin Zi	3.57 ab	1.29 a	19.54 bc	19.63 ab	30.70 cde	74.75 bcd
Hong Baoshi	3.27 ab	1.17 ab	15.88 def	16.11 c	27.76 defg	64.17 ef
Hongxia Yingyue	3.32 ab	0.97 ab	15.95 def	16.77b c	27.72 defg	64.74 def
Mochi Jin Hui	3.53 ab	1.16 ab	19.25 bcd	17.98 bc	33.34 bc	75.26 bc
Mo Run Jue Lun	3.69 a	1.28 a	22.39 ab	21.84 a	37.01 ab	86.21 a
Sai Huanghou	2.90 bc	0.86 b	15.31 ef	12.09 d	25.57 fg	56.75 fg
Xiang Yu	2.50 c	1.12 ab	13.82 f	12.12 d	23.50 g	53.07 g
Yinhong Qiaodui	3.28 ab	0.97 ab	16.93 cdef	16.53 c	27.49 defg	65.21 def
Zi Ju	3.13 abc	1.04 ab	19.14 bcd	17.32 bc	28.70 def	69.33 bcde
Significance	*	NS	**	**	**	**

^zIn each column, the means followed by the same letters are not significantly different at a 5% level of probability.

NS, *, **Nonsignificant or significant at 0.05 and 0.01, respectively.

Fig. 4. Estimated seed oil content per fruit for various pollen sources in the pollen source experiment.

These results emphasize the crucial effects of the pollen source in determining the oil yield in tree peony plantations. The variability in the oil content has been considered to be mostly dependent on the mother plant genotype, whereas xenia effects also had a certain impact on the oil content of hybrid seeds (Wang et al., 2010). During the development of fruit, the nutrients are not only supplied by the mother plant but also synthesized and stored by its own embryo (Dure, 1975). Therefore, the genotype of the embryo might also affect the level of oil content in the kernel. The fact that there was no significant difference in the oil extraction ratio between self- and cross-pollinated kernels could also be explained by this result.

The FA profile showed significant differences in the PA, OA, LA, and ALA among pollen sources, which reveals a great potential for improving the seed oil composition of *P. ostii* 'Feng Dan' by applying proper pollen. Similar results were observed by Kodad et al. (2009) in almonds and Samocha et al. (2014) in *Jatropha curcas* L. Previous studies indicated that some fruit chemical compositions in other species could also be influenced by different pollen sources. The pollen source affected the total soluble solids of the fruit in date palms (*Phoenix dactylifera* L.) (Rezazadeh et al., 2013) and the amygdalin content in almonds (Sanchez-Perez et al., 2012). The variation among pollen sources in oil composition could be contributed by its own embryo,

which is affected by both the mother and father genotypes (Kodad et al., 2009).

Conclusions

Our study provides evidence for the effects of different pollination treatments on the characteristics of the fruits and seeds of *P. ostii* 'Feng Dan'. Decreases in fruit setting, seed number per fruit, and in the volume and weight of the seed are observed after self-pollination. Moreover, self-pollination also results in an increase in OA content and a decrease in LA content in seed oil. Our results also confirm the significant effect of pollen sources on the phenotypic traits of seeds and major FA composition of their oil. Therefore, we proposed that the appropriate selection of pollen sources would be a key strategic measure for improving the quantity and quality of seeds of *P. ostii* 'Feng Dan'.

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