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Xenia Effects on Oil Content and Fatty Acid and Tocopherol Concentrations in Autogamous Almond Cultivars

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The increasing utilization of self-compatible almond cultivars in solid plantings of a single genotype has raised the question of the effect of the pollen source on the kernel quality of these new autogamous cultivars. Thus, the effect of two different pollen sources, in addition to their own pollen, on the oil content and fatty acid and tocopherol concentrations was studied in four autogamous almond genotypes. The oil content was not affected by the pollination treatment, but self-pollination resulted in significantly higher values for oleic acid. For the tocopherol homologues, the α-tocopherol content of the self-pollinated kernels was intermediate between those obtained after cross-pollination with the two foreign pollens, but the self-pollinated kernels had higher values of δ-tocopherol than the cross-pollinated kernels. Thus, the effect of the pollen source was shown to have a clear effect on the fatty acid composition but not on the oil or tocopherol contents of the almond kernels, with an increased quality of the kernels produced after self-pollination because of a higher oleic/linoleic acid ratio.

KEYWORDS: Almond; fatty acid composition; kernel quality; oil content; *Prunus amygdalus* Batsch; self-pollination; tocopherol content; xenia

INTRODUCTION

The edible part of the almond (*Prunus amygdalus* Batsch) nut is the kernel, considered an important food crop with a high nutritional value. The almond kernels must have a high quality to fulfill the industry requirements and be attractive for the consumers. In addition to the kernel physical traits (*1*), the chemical composition of the kernel is essential when considering the different industrial applications and the high diversity of almond confectioneries. Taking into account the high concentration of lipids in the almond kernel, the quality of the almond oil appears as the most important feature in the evaluation of almond quality. Several elements of the lipid fraction of the kernel have been suggested as parameters for quality evaluation in almond kernels, including the amount of oil content, the percentage of oleic acid in the lipid fraction, the ratio of oleic/linoleic acids (O/L), and the tocopherol concentration (*1*−*5*). Tocopherols are natural monophenols with antioxidant activities, with several homologues depending on the position and the number of methyl groups on the ring structure. Their main biochemical function is believed to be the protection of polyunsaturated fatty acids against peroxidation (*6*).

Oil stability and fatty acid composition, essentially the O/L ratio (*3*), are considered important criteria to evaluate kernel quality because of the kernel tendency to rancidification during storage and transport, giving as a result a loss of quality related to the oxidation of the kernel fatty acids. A high concentration of tocopherols has also been shown to be very important in the human diet, due to their vitamin E activity (*6*). Interest in vitamin E has increased in recent years due to its potent antioxidant properties and its role in preventing age-related diseases, cardiovascular diseases, or Alzheimer's disease (*7*). Consequently, kernel quality may also be increased by higher levels of α-tocopherol, due to its lipid stability function and nutritive value, taking into account the present consumers' preferences for foods without synthetic additives (*8*).

Recently, self-compatible almond cultivars have been released to avoid the problems related to almond pollination and to be planted in orchards of a single cultivar (*9*). Previous results have shown that self-pollination may have a negative effect on the final fruit size (*10*, *11*), although with clear differences between genotypes (*10*) and also with cases where self-pollination did not affect the physical traits of the almond fruits (*12*). Most studies have only considered the influence of self-pollination on some physical traits, but information on the effect of self-pollination on the chemical composition of the almond kernels is scarce. The only report has shown that in most cases self-pollination decreased the concentration of linoleic acid and increased that of oleic acid, thus increasing a quality parameter such as O/L (*10*). As a consequence, the kernels produced after self-pollination could be more resistant to rancidification because of this O/L ratio increase. However, no reports have considered the effect of self-pollination in another important trait of almond quality, the concentration of tocopherols in almond kernel oil.

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All of the previous studies on the effect of self-pollination on almond fruit traits have utilized a single source of foreign pollen in the cross-pollination treatments or unknown pollen in the case of open pollination. In any case, the possibility of xenia, the direct effect of pollen on the endosperm because of the pollination by different pollen sources on the traits studied, cannot be excluded. As a consequence, our aim was to study the possible effect of the pollen source on the chemical composition of the almond kernels in four self-compatible genotypes following their self-pollination and cross-pollination with two different foreign pollen sources, considering that the oil content and the fatty acid and tocopherol concentrations are parameters for quality evaluation in almond kernels.

MATERIALS AND METHODS

Plant Material. Three releases from the CITA breeding program, 'Felisia', 'Guara', and 'Mardía', and one advanced selection, I-2-12, were included in this study. The trees were grown in the Spanish almond germplasm collection (*13*). As much as possible, homogeneous branches were used for artificial pollinations, and the different treatments were applied to two branches per treatment as already described (*14*). The treatments included self-pollination and cross-pollination with the pollen of 'Marcona' and 'Fournat de Brézenaud' to ascertain the effect of the pollen source on the expression of the traits considered. Nuts were harvested at maturity, when fruit mesocarp was fully dried and split along the fruit suture and peduncle abscission was complete. Two samples of 20 fruits were collected for each treatment.

Oil and Fatty Acid Determination. After blanching, the kernels were ground in an electrical grinder. Oil was extracted from 4 to 5 g of ground almond kernel in the commercial fat extractor Soxtec Avanti 2055 (Tecator, Barcelona, Spain) for 2 h using petroleum ether as the solvent and keeping the heating source at 135 °C because previous checks showed that extraction was practically completed after 2 h, with no differences after 4 h (*5*, *15*). The oil content was expressed as the difference in weight of the dried kernel sample before and after extraction. The oil sample was utilized to prepare the methyl esters of the corresponding fatty acids (fatty acid methyl esters, FAMEs) by trans-etherification with KOH according to the official method UNE-EN ISO 5509:2000 (February, 2001). These methyl esters were separated using a flame ionization detector (FID) gas chromatograph HP-6890 equipped with a HP-Innowax column of 30 m × 0.25 mm i.d. and 0.25 μm film thickness (Agilent Technologies, Waldbronn, Germany). The carrier gas was helium at a flow rate of 1 mL/min. The temperatures of the inlet and detector were maintained at 220 and 275 °C, respectively. The initial column temperature was 100 °C for 3 min. The oven temperature was increased from 100 to 150 at 20 °C/min ramp rate for 1 min, from 150 to 200 at 15 °C/min ramp rate for 3 min, and from 200 to 240 at 3 °C/min ramp rate. The temperature was maintained at 240 °C for 4 min. The injection volume was 1.0 mL. The identification of the FAMEs was achieved by comparison with relative chromatographic retention times in a reference sample that contained standard methyl esters (Sigma-Aldrich, Madrid, Spain). The results were expressed as percentages of each fatty acid in the total oil amount.

Tocopherol Determination. The separation and later quantification of the three main tocopherol homologues (α, γ, and δ) were performed by high-resolution liquid chromatography (HPLC), in reverse phase and isocratic ways. Identification of chromatographic peaks was based on retention times by comparison with known standards (Sigma-Aldrich). An external calibration curve was prepared for each tocopherol standard to calculate the amount of tocopherols present in the oil sample.

The procedure applied was a modification of a method already described (*15*). Samples of 0.3 g of almond oil were dissolved in 2 mL of 1-propanol by shaking at air temperature for 30 s. After 10 min of rest in dark, 20 μL of the propanolic extract was injected in a HPLC 360 (Kontron, Milan, Italy), equipped with a double piston pump, self-sampler, and regulated furnace at 30 °C. The column used was a 250 mm × 4.6 mm i.d., 5 mm, Luna 100 RP-18 (Phenomenex, Torrance, CA). The mobile phase was an isocratic elution of acetonitrile:methanol (30/70). Detection of δ- and γ-tocopherol was done using a FLD SFM25 fluorescence detector (Kontron) under an excitation wavelength of 295 nm and emission of 325 nm. Detection of α-tocopherol was done with a DAD 440 diode array detector (Kontron) at a wavelength of 295 nm.

The lineal ranges for the concentration determination of each homologue were as follows: 20−200 mg/kg for α-tocopherol, 0.1−8 mg/kg for γ-tocopherol, and 0.05−5 mg/kg for δ-tocopherol. This method has allowed a mean recovery of 98%, a relative standard deviation (RSD, reproducibility) between 5 and 15% depending on the homologue analyzed, and a linearity coefficient >0.97 in the working range. Tocopherol compositions were the mean values of two replicates of each of the three extractions from every sample and were expressed as mg/kg oil.

Statistical Analysis. All of the statistical analysis was performed with the SAS 2000 program (SAS Institute, Cary, NC). The analysis of variance with the PROC GLM procedure was applied. The mean separation was done with the least significant difference (LSD) test at a probability of 0.05.

RESULTS AND DISCUSSION

Pollen Effect on Oil and Fatty Acids. As expected, the genotype effect was significant for the oil content and the fatty acid composition (**Table 1**). Independently of the pollen source, selection I-2-12 showed the highest oil content, and 'Felisia' showed the lowest. Concerning the fatty acid composition, 'Guara' showed the highest values of palmitic, stearic, and linoleic

Table 1. Analysis of Variance for the Kernel Components of Four Almond Genotypes

		statistics			
component	source of variation	df	mean square	*F* value	*P* value
total oil	genotype	3	72.60	15.96	0.0002
	treatment	2	8.57	1.88	0.1944
	genotype × treatment	6	15.70	3.45	0.0322
	error	23	383.71	4.54	
C16:0	genotype	3	0.46	38.35	<0.0001
	treatment	2	0.05	4.11	0.0436
	genotype × treatment	6	0.05	4.1	0.0181
	error	23	1.92		
C16:1	genotype	3	0.009	12.74	0.0005
	treatment	2	0.0003	0.46	0.6403
	genotype × treatment	6	0.0007	1.09	0.4224
	error	23	0.04		
C18:0	genotype	3	0.40	5.93	0.0101
	treatment	2	0.04	0.59	0.5676
	genotype × treatment	6	0.12	1.82	0.1775
	error	23	2.83		
C18:1	genotype	3	58.15	187.68	<0.0001
	treatment	2	5.15	16.61	0.0003
	genotype × treatment	6	10.52	33.95	<0.0001
	error	23	251.5		
C18:2	genotype	3	44.62	287.79	<0.0001
	treatment	2	3.46	22.34	<0.0001
	genotype × treatment	6	9.93	64.07	<0.0001
	error	23	202.2		
O/L	genotype	3	2.70	449.99	<0.0001
	treatment	2	0.15	25.14	<0.0001
	genotype × treatment	6	0.49	81.73	<0.0001
	error	23	11.39		
α-tocopherol	genotype	3	29858.83	7.33	0.0104
	treatment	2	3153.73	4.1	0.0439
	genotype × treatment	6	3363.33	1.11	0.4091
	error	23	176879.07		
γ-tocopherol	genotype	3	117.43	10.48	0.0011
	treatment	2	32.01	2.86	0.0966
	genotype × treatment	6	34.47	3.08	0.0461
	error	23	757.5		
δ-tocopherol	genotype	3	0.91	12.45	0.0005
	treatment	2	0.34	4.65	0.0319
	genotype × treatment	6	0.54	7.47	0.0017
	error	23	7.52		

Table 2. Mean Values of Oil, Fatty Acid, and Tocopherol Concentrations of the Studied Genotypes Independent of the Treatment[a]

	genotype			
component	Felisia	Mardía	Guara	I-2-12
oil	54.18 ± 4.72 c	60.7 ± 1.52	58.60 ± 2.83 b	62.13 ± 0.76 a
C16:0	6.46 ± 0.16 b	5.96 ± 0.16	6.61 ± 0.23 a	6.35 ± 0.07 b
C16:1	0.54 ± 0.02 a	0.50 ± 0.01	0.46 ± 0.04 c	0.45 ± 0.02 c
C18:0	1.68 ± 0.27 c	2.06 ± 0.07	2.31 ± 0.43 a	1.96 ± 0.25 bc
C18:1	68.66 ± 2.95 c	74.34 ± 0.74	67.19 ± 1.35 d	70.93 ± 2.08 b
C18:2	21.73 ± 2.76 b	16.55 ± 0.54 d	22.72 ± 1.22 a	19.65 ± 2.06 c
O/L	3.22 ± 0.58 c	4.49 ± 0.15	2.96 ± 0.23 d	3.65 ± 0.50 b
α-tocopherol	267.5 ± 47.41 a	336.69 ± 56.9	435.4 ± 41.43 c	380.2 ± 51.1 ab
γ-tocopherol	21.16 ± 4.75 a	10.66 ± 3.09	18.21 ± 4.36 ab	16.75 ± 5.47 b
δ-tocopherol	1.60 ± 0.78 a	0.68 ± 0.30	1.07 ± 0.31 b	0.94 ± 0.40 bc

[a] The oil content is given as a percentage of kernel dry weight; the fatty acid composition is given as a percentage of total oil content; the tocopherol homologues are given as mg/kg oil. Values followed by different letters in the same column are significantly different at $P < 0.05$.

Table 3. Mean Values of Oil, Fatty Acid, and Tocopherol Concentrations of the Studied Genotypes for Each Pollination Treatment[a]

	pollen treatment		
variable	self-pollination	Fournat de Brézenaud	Marcona
oil	58.63 ± 2.95 a	60.08 ± 2.92 a	58.07 ± 3.93 a
C16:0	6.27 ± 0.21 ab	6.35 ± 0.38 ab	6.43 ± 0.27 a
C16:1	0.49 ± 0.06 a	0.48 ± 0.03 a	0.49 ± 0.04 a
C18:0	1.98 ± 0.52 a	1.95 ± 0.20 a	2.08 ± 0.29 a
C18:1	71.03 ± 2.69 a	69.43 ± 3.46 c	70.37 ± 3.91 b
C18:2	19.67 ± 2.12 b	20.91 ± 3.32 a	19.70 ± 3.52 b
O/L	3.65 ± 0.53 a	3.66 ± 0.77 a	3.42 ± 0.85 b
α-tocopherol	359.58 ± 86.8 a	330.49 ± 81.33 b	368.95 ± 61.05 a
γ-tocopherol	18.05 ± 7.49 a	17.64 ± 3.33 a	16.40 ± 5.65 a
δ-tocopherol	1.28 ± 0.85 a	0.87 ± 0.27 b	1.07 ± 0.42 ab

[a] The oil content is given as a percentage of kernel dry weight; the fatty acid composition is given as a percentage of total oil content; the tocopherol homologues are given as mg/kg oil. Values followed by different letters in the same line are significantly different at $P < 0.05$.

acids. 'Mardía' showed the highest values of oleic acid and the O/L ratio, whereas 'Guara' showed the lowest (**Table 2**).

In general, the pollination treatments did not affect the oil content of these genotypes (**Table 1**), although cross-pollination with 'Fournat de Brézenaud' slightly increased the percentage of kernel oil content but not significantly (**Table 3**). Considering each genotype, the treatment effect was statistically significant for the oil content in 'Guara' and 'Felisia' but not in the other genotypes. The lowest values were observed in 'Felisia' after cross-pollination with 'Marcona', whereas in 'Guara' the lowest values were found after self-pollination (**Table 4**).

The treatment effect was significant for palmitic, oleic, and linoleic acid concentrations and for the O/L ratio but not for the total oil content and for the palmitoleic and stearic acid concentrations (**Table 1**). For oleic acid, self-pollination produced the highest values, followed by cross-pollination with 'Marcona' and finally by cross-pollination with 'Fournat de Brézenaud' (**Table 3**). These results show a clear effect of pollen source on the fatty acid composition of self-compatible almond genotypes, mainly on oleic and linoleic acids, as previously reported (*10*).

The interaction genotype × treatment was significant for most traits, with the exception of palmitoleic and stearic acids (**Table 1**), showing that the values of the different fatty acids coming from different pollinations change of range depending on each selection. Thus, a statistical analysis was applied at the individual level to ascertain if self-pollinated kernels had higher amounts of oleic acid (**Table 4**). Self-pollinated kernels of 'Guara' and 'Felisia' had a higher amount of oleic acid than the cross-pollinated kernels. However, the opposite was observed in 'Mardía', whereas in selection I-2-12 no differences were observed between treatments for oleic acid concentration (**Table 4**). In 'Guara', the self-pollinated kernels had a lower oil content than the cross-pollinated ones, whereas in the other cultivars no significant differences were observed between the two types of pollination (**Table 4**).

Pollen Effect on Tocopherol Concentration. The tocopherol homologue concentration showed significant differences between genotypes (**Table 1**). Independently of the treatment, 'Guara' showed the highest value of α-tocopherol (436.7 mg/kg of oil), followed by I-2-12 (383.5 mg), 'Mardía' (336.8), and 'Felisia' (258.7 mg). For δ-tocopherol, 'Felisia' showed the highest value (1.6 mg/kg of oil), followed by 'Guara' (1.07 mg), I-2-12 (0.94 mg), and 'Mardía' (0.68 mg). The treatment effect was significant for α- and δ-tocopherol but not for γ-tocopherol (**Table 1**). The α-tocopherol content of the self-pollinated kernels was intermediate between those obtained after cross-pollination with 'Fournat de Bréznaud' and 'Marcona'. However, the self-pollinated kernels had higher values of δ-tocopherol than the cross-pollinated kernels. No significant differences were found between treatments for γ-tocopherol (**Table 3**). For each genotype, no significant differences were found for α-tocopherol between self- and cross-pollination in 'Guara' and I-2-12 but were significant in 'Mardía' and 'Felisia' (**Table 4**).

In all cultivars, the effect of the pollen source was not clear for the concentrations of the three tocopherol homologues because any trend was observed. For γ-tocopherol, self-pollination produced in 'Guara' and 'Felisia' had the highest value, but in 'Mardía', the effect was the contrary (**Table 4**). These results explain the significant effect of the interaction genotype × treatment (**Table 1**), showing that the values of the different homologues may change of range depending on each genotype.

Xenia Effects on Quality. The quality of many almond confectioneries depends on the oil content in the kernels (*16*). Thus, any factor affecting the amount of the oil content in almond kernels is extremely important when determining their best possible industrial utilizations. It has already been clearly established that growing self-compatible almond cultivars in solid orchards of a single cultivar is feasible considering only yield and the physical quality of the kernels (*17*), but their chemical quality must also be taken into account. Although it has already been reported that the oil content was lower in almond kernels obtained by self-pollination than by open pollination (*10*), our global results indicate that the pollen source does not affect the oil content of almond kernels, even if this effect was observed at the individual level in 'Guara' and 'Felisia'. In the self-incompatible almond 'Nonpareil', no significant effects of pollen source on the oil content were observed (*18*), showing that the xenia effects may depend on the cultivar. However, in another species such as olive (*Olea europea* L.), self-pollinated fruits of some olive cultivars grown in Egypt had lower oil contents than those obtained after cross-pollination (*19*).

The variability of the oil content in almond kernels has been considered to be mostly dependent on the mother plant genotype, the environmental effect being weak (*2*, *10*, *20*). However, during embryogenesis, in addition to the nutrients supplied by the mother plant, the own embryo also synthesizes and stores an important fraction of nutrients (*21*). Thus, taking into account that oil accumulation only takes place when the cotyledon reaches a certain maturity level (*22*), the embryo genotype might also affect the level of oil content in the kernel. As a consequence, the oil content depends on two different genotypes, that of the mother plant and that of the resulting embryo, which shares half of its

Table 4. Mean Values of Oil, Fatty Acids, and Tocopherol Concentrations for Each Genotype and Pollination Treatment[a]

	genotype											
	Felisia			Mardía			Guara			I-2-12		
component	AP1[c]	AP3	AP2	AP1	AP3	AP2	AP1	AP3	AP2	AP1	AP3	AP2
oil	56.35 ± 0.02 a	56.83 ± 3.66 a	52.80 ± 0.15 b	60.31 ± 0.31 a	61.2 ± 1.12 a	60.79 ± 2.02 a	56.86 ± 2.86 b	60.38 ± 0.27 a	59.65 ± 0.03 a	61.51 ± 0.33 a	61.89 ± 0.33 a	62.99 ± 0.16 a
C16:0	6.36 ± 0.06 a	6.44 ± 0.01 a	6.59 ± 0.18 a	5.94 ± 0.01 a	5.85 ± 0.16 a	6.11 ± 0.03 a	6.34 ± 0.08 a	6.81 ± 0.01 a	6.70 ± 0.01 a	6.44 ± 0.02 a	6.30 ± 0.01 b	6.31 ± 0.02 b
C16:1	0.55 ± 0.03 a	0.52 ± 0.02 a	0.55 ± 0.01 a	0.51 ± 0.03 a	0.49 ± 0.01 a	0.51 ± 0.01 a	0.48 ± 0.06 a	0.46 ± 0.02 a	0.44 ± 0.01 a	0.43 ± 0.01 b	0.46 ± 0.01 ab	0.48 ± 0.01 a
C18:0	1.37 ± 0.03 c	1.97 ± 0.02 a	1.72 ± 0.01 b	2.15 ± 0.02 a	2 ± 0.05 ab	2.06 ± 0.01 b	2.12 ± 0.63 a	2.34 ± 0.01 a	2.47 ± 0.03 a	1.65 ± 0.06 b	2.1 ± 0.01 a	2.15 ± 0.04 a
C18:1	72.30 ± 0.20 a	65.99 ± 0.09 b	67.68 ± 0.61 b	74.41 ± 1.08 a	73.99 ± 0.03 a	74.63 ± 0.04 a	68.83 ± 0. 62 a	66.79 ± 0.52 b	65.95 ± 0.05 b	72.88 ± 0.27 a	68.59 ± 0.07 b	73.22 ± 0.03 a
C18:2	18.33 ± 0.15 c	24.33 ± 0.04 a	22.55 ± 0.29 b	17.25 ± 0.03 a	16.28 ± 0.04 b	16.13 ± 0.03 b	21.38 ± 0.89 b	23.04 ± 0.03 a	23.74 ± 0.07 a	19.05 ± 0.12 b	21.75 ± 0.09 a	17.19 ± 0.03 c
O/L	3.94 ± 0.02 a	3.05 ± 0.01 b	2.71 ± 0.07 c	4.54 ± 0.07 a	4.31 ± 0.01 a	4.63 ± 0.01 a	3.22 ± 0.15 a	2.89 ± 0.04 ab	2.78 ± 0.01 b	3.55 ± 0.03 b	3.15 ± 0.02 c	4.26 ± 0.01 a
α-T[b]	290.5 ± 20.35 a	225.8 ± 19.59 a	286.2 ± 45.16 a	346.2 ± 45.35 a	312.4 ± 47.17 a	351.4 ± 25.2 a	442.3 ± 35.3 a	448.38 ± 20.30 a	415.5 ± 44.2 a	368.4 ± 10.25 a	360.6 ± 37.4 a	411.6 ± 49.63 a
γ-T	27.11 ± 0.09 a	19.15 ± 1.26 b	17.24 ± 0.09 b	8.18 ± 0.48 a	12.89 ± 2.89 a	10.91 ± 2.02 a	21.17 ± 1.10 ab	15.23 ± 0.55 b	18.25 ± 5.3 ab	15.74 ± 0.49 ab	12.24 ± 3.17 b	22.27 ± 3.59 a
δ-T	2.54 ± 0.05 a	1.43 ± 0.18 b	0.83 ± 0.06 c	0.43 ± 0.07 b	1.02 ± 0.18 a	0.59 ± 0.05 ab	1.35 ± 0.02 a	0.87 ± 0.05 a	0.98 ± 0.35 a	0.80 ± 0.11 ab	0.75 ± 0.28 b	1.27 ± 0.39 a

[a] The oil content is given as a percentage of kernel dry weight; the fatty acid composition is given as a percentage of total oil content; tocopherol homologues are given as mg/kg oil. Values followed by different letters in the same line are significantly different at $P < 0.05$. [b] δ-, γ-, and α-totocopherol homologues. [c] AP1, self-pollination; AP2, pollen of 'Marcona'; and AP3, pollen of 'Fournat de Brézenaud'.

genotype with the mother plant, thus confirming the primary importance of the cultivar producing the fruits. The fact that the final quality may not be affected by a light decrease in the oil content is also important, as shown in the self-pollinated kernels of 'Guara', whose chemical composition is very similar to that of the open-pollinated kernels, similar to what was observed for their physical parameters (*9*, *12*). Thus, the effect of the pollen source may also be dependent on the plasticity of the mother plant.

The fatty acid profile showed significant differences for the palmitic, oleic, and linoleic acids depending on the pollination treatment. Mean separation by LSD showed an increase of oleic acid after self-pollination and a decrease after cross-pollination, agreeing with previous results (*10*). At the individual level, the same results were found, except for I-2-12, where no differences were found for oleic acid, probably due to a lower plasticity of this selection. The values for these acids in kernels obtained by 'Marcona' pollination were significantly higher than those obtained by 'Fournat de Brézenaud' pollination. These results may be related to the oleic acid content in these two cultivars, because in 'Marcona' (71%) is higher than in 'Fournat de Brézenaud' (67%). A similar effect of the pollen parent has been also observed in Ethiopian mustard, *Brassica carinata* A. Braun (*23*).

The pollination treatment has been found to be significant for the fruit chemical composition in other species. In Japanese plum (*P. salicina* Lindl.), cross- and open pollination improved the chemical characteristics of the fruits, especially total soluble solids and total sugars (*24*). In dates (*Phoenix dactylifera* L.), the pollen source affected the total soluble solids of the fruit (*25*). However, in 'Pam' muscadine grape (*Vitis rotundifolia* Michx.), no differences in the fruit soluble solids content were found among the fruits derived from different pollen sources (*26*). These results show that even if the pollen source affects the chemical composition of fruits, this effect may depend on the specificity of each genotype and the affinity between genotypes of the same species.

Almond kernels consist of the embryo, the endosperm, and the seed coat. In the mature kernel, the endosperm remains as a well-formed aleurone layer, which is closely connected with the seed coat. Therefore, the compounds considered for kernel quality are mainly located in the diploid seed cotyledons rather than in the endosperm, as is typical for many monocotyledonous plants. In oilseed rape (*Brassica napus* L.), the content of oleic acid was found to be determined by the genotype of the embryo (*27*). The differences between treatments found in the present study may suggest that the own embryo also contributes to the oil composition, which is thus affected by both the mother and the father genotypes. The decrease of linoleic acid for the self-pollination treatment and its increase for the cross-pollination treatment may be due to the negative correlation between the percentages of oleic and linoleic acids (*2*, *10*, *28*).

The pollen effect on tocopherol content had not been studied so far in almond. As a consequence, our results cannot be compared. The tocopherol concentrations have shown significant differences depending on the pollination treatment, except for γ-tocopherol. In general, mean separation by LSD showed an increase of δ- and γ-tocopherol after self-pollination. At the individual level, self-pollinated kernels had a higher δ- and γ-tocopherol concentration in 'Felisia' and 'Guara' but not in the other genotypes. For α-tocopherol, the most important homologue, cross-pollination with 'Fournat de Brézenaud' produced kernels with a lower concentration, followed by those from self-pollination. This pollen effect may also be related to the higher α-tocopherol concentration in 'Marcona' kernels (481.5 mg/kg oil) than in 'Fournat of Brézenaud' kernels (399.7 mg/kg oil). At the individual level, no tendency was observed, although

the ranking of genotypes was maintained in all treatments ('Guara', 'Mardía', I-2-12, and 'Felisia'). The heritability of these components was found to be high, 0.59 (*29*), indicating that the α-tocopherol content depends on the genotype. However, the environmental conditions, mainly temperature, largely affect the tocopherol concentration in the almond kernels (*4*).

As a conclusion, self-pollination can be considered beneficial for the quality of the almond kernels because the xenia effects of the own pollen were not significant for the amount of tocopherol but showed a light increase in the amount of oil and a significant increase in the amount of oleic acid and the O/L ratio, both parameters of kernel quality.

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LITERATURE CITED

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