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Felama® Almond

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The almond breeding program at the Agrifood Research and Technology Center of Aragon (CITA) began in 1974, focusing on self-compatibility and late flowering while ensuring fruit quality and productivity in new planting systems. Self-compatible cultivars are crucial in modern plantations. 'Aylés', 'Moncayo', and 'Guara' were the program's initial releases (Felipe and R Socias i Company 1987), with 'Guara' being the first cultivar introduced to the industry in Spain in 1988 combining self-compatibility and late flowering. Other self-compatible cultivars released in the early stages of the breeding program were 'Blanquerna', 'Cambra', and 'Felisia' (R Socias i Company and Felipe 1999). New self-pollinating cultivars with high fruit quality have been selected. In 2005, Soleta® and Isabelona® were introduced, both self-pollinating, late-flowering, and of high fruit quality (Bielsa et al. 2021; R Socias i Company and Felipe 2007). These varieties have been widely used in high-density planting systems. Two extralate flowering cultivars were released, Mardía® and Vialfas® (R Socias i Company et al. 2008, 2015). The introduction of late and very late flowering cultivars has significantly reduced frost damage and allowing the expansion of almond cultivation inland Spain. Felama® has recently been released due to its high productivity, medium vigor, uniform and balanced branching, late flowering, and early fruit maturation, indicating high marketability in areas without the risk of spring frost.

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Origin

The almond cultivar Felama® (selection 'I-3-67') originated from the cross between 'Felisia' and 'Moncayo'. 'Felisia', from CITA's breeding program, is self-compatible, with extra late flowering and small almonds. 'Moncayo', also from CITA, is self-compatible with late flowering and a very hard shell. The aim of the cross was to combine two late-flowering almond varieties, one of which carries the Lb allele for late flowering (R Socias i Company et al. 1999). These varieties have different almond sizes and are genetically distant from another.

Blooming Time

On average, Felama® blooms 2 days before Soleta® and Isabelona® and 24 d after 'Desmayo Largueta' (Fig. 1) (Felipe et al. 2022; García 2023). This delay is attributed to Felama®'s high requirements of cold and heat (Alonso et al. 2005; Alonso and R Socias i Company 2009). Regarding heat requirements, Felama® has growing degree day (GDD) values similar to Soleta® and Isabelona®, making it suitable for areas without risk of spring frosts (García 2023). The flowers are medium-sized, white, and distributed on 1-year shoots and spurs, with intermediate density.

Autogamy

Self-compatibility was assessed by monitoring the arrival of pollen tubes at the ovary following self-pollination (data not shown) and fruit set after self-pollination and self-fertilization on covered trees during bloom. The presence of the Sf gene (Channuntapipat et al. 2003) was also evaluated to confirm Felama®'s self-compatibility (data not shown).

Performance

Field performance was evaluated in an experimental plot in Caspe (Zaragoza), a region with moderately cold winters and high chilling accumulation, followed by warm springs and extremely hot summers, favoring early fruit tree ripening (Alonso et al. 2016). Felama® trees grafted onto 'GF-677' rootstocks showed a TCSA (Trunk Cross Section Area) value similar to Isabelona® and Soleta® cultivars (Table 1), but without apical dominance, unlike Isabelona® and 'Guara' (Montesinos et al. 2021, 2023). This medium vigor could enable Felama® to adapt well to denser plantings compared with cultivars with higher apical dominance. Felama® exhibited the highest accumulative yields and productivities, close to Vialfas® and 'Guara' (Table 2) in a traditional planting system over 6 years (Alonso et al. 2016). Compared with 'Guara', Felama®, did not show any issues with branch bending (Fig. 2). Felama® trees have a moderate level of flowering and balanced branching density, reducing the need for pruning. Its harvest is early, with a 10-day gap from 'Guara', allowing for consecutive harvesting. Preharvest nut shedding has been minimal yet is easy to harvest. The yield rating for various late-blooming cultivars and breeding selections evaluated in a trial was marginally lower than 'Guara' (Alonso et al. 2016), which is considered a high-yield cultivar, having received a rating of 9 on the same scale in a previous study (Alonso et al. 2012).

Industrial Quality and Composition

Felama® fruits were evaluated over 7 years according to criteria established by the International Union for the Protection of New Varieties of Plants. The average weight was 3.86 g, 28.58 mm in length, and 23.55 mm in width, with a rounded-oval shape (Fig. 3). The shell, accounting for 32% of the total weight, is ideal for the Spanish industry due to its hardness. The kernels, averaging 1.04 g in weight and length and width of 21.51 and 14.83 mm, respectively, are oval-shaped. In certain rootstocks Felama® exhibited 1.5% to 3.9% of double almonds and wrinkled kernels, which could be attributed to water issues during ripening. It is easy to peel (Fig. 3).

Felama® showed comparable levels of polyphenols and proanthocyanidins, as well as antioxidant capacity similar to other cultivars (Table 3) (Moreno Garcia et al. 2021).

The oleic acid content, indicator of nutritional quality and fat stability, is high, reaching 74% (Table 4) (Kodad and R Socias i Company 2008). The content of linoleic acid, less stable, is low, with an oleic/linoleic acid ratio of 4.2, indicating high oil quality. Tocopherols, with a content of 407.1 (Kodad et al. 2006), necessitate prompt processing post-harvest.

Availability

It is available for nurseries through commercial licenses by Geslive, S.L. C. Antonia Maura 7 1° Izda, 28014, Madrid, Spain.

E-mail: administracion@geslive.com.

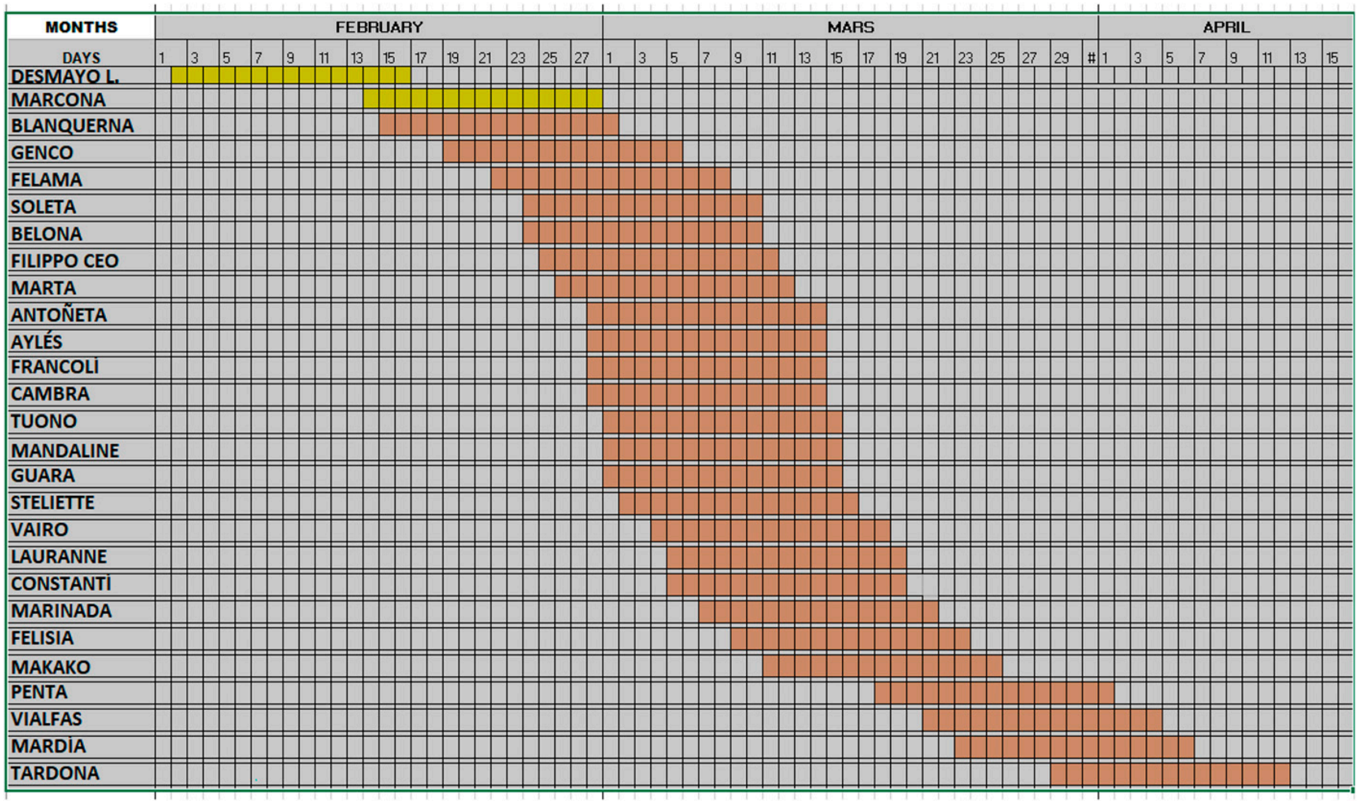

Fig. 1. Mean flowering time of Felama® as related to known cultivars (2 years average in different rootstocks). Percentages refer to the number of flowers opened.

Table 1. The results of the 7-year trial on four different rootstocks for trunk cross section area (TCSA) are presented. Statistical significance ($P \leq 0.05$) among cultivars for each rootstock is indicated by different letters.

Rootstock	Cultivar	Vigor-TCSA (cm^2)
'GF-677'	Felama®	63.5 a
	Isabelona®	49.0 a
	Soleta®	56.5 a
Monegro®	Felama®	61.1 a
	Isabelona®	43.1 a
	Soleta®	53.7 a
Garnem®	Felama®	88.3 b
	Isabelona®	21.5 ab
	Soleta®	34.6 a

Table 2. Results of kernel percentage, accumulated yield, and productivity of the Felama® cultivar compared with other commercial cultivars and Technology Centre of Aragon selections (Alonso et al. 2016). Statistical significance ($P \leq 0.05$) among cultivars is indicated by different letters.

		Kernel percentage		Accumulated yield (2009–14)				
				Unshelled nut		Kernel		
Genotype	Vigor-TCSA (cm^2)	Whole nut	Shell almond	kg/tree	kg/ha	kg/tree	kg/ha	Productivity (g/cm^2)
Vialfas®	166.2 e	20.4 b	25.3 c	56.6	13.5 bc	14.3	3.4 b	85.9 a
'G-3-4'	199.4 de	19.4 b	24.9 c	26.9	6.4 g	6.7	1.6 e	33.6 d
'G-3-3'	203.1 de	20.9 b	26.5 bc	35.5	8.4 efg	9.4	2.2 de	6.4 c
Mardía®	215.9 cde	21 b	24.9 c	40.2	9.6 def	10	2.4 cd	46.2 c
'G-5-25'	219.6 cde	20.4 b	25 c	59.2	14 bc	14.8	3.5 b	67.3 b
'G-2-22'	255.9 bcd	19.6 b	24.9 c	33.7	8 gf	8.4	2 de	32.9 d
Felama®	258.7 bce	23.2 b	29.3 bc	76.7	18.3 a	22.5	5.4 a	86.9 a
'Guara'	275.8 abc	28.4 a	35.8 a	66.4	15.8 bc	23.8	5.7 a	86.1 a
Isabelona®	303 ab	22.4 b	28.4 bc	45.4	10.8 de	12.9	3 bc	42.4 cd
Soleta®	326.3 a	22.5 b	30 b	54.3	12.9 cd	16.3	3.9 b	49.9 cd

TCSA = trunk cross section area.

Fig. 2. Felama® tree in full production and branching.

Fig. 3. Nut and kernel of Felama.®

Table 3. The Felama® cultivar exhibits average levels of polyphenols, flavonoids, proanthocyanidins, and antioxidant capacity compared with other almond genotypes (Moreno et al. 2021). Statistical significance ($P \leq 0.05$) between cultivars is indicated by different letters.

Genotype	Polyphenols (mg GAE/100 g)	Flavonoids (mg CAT/100 g)	Proanthocyanidins (mg CYN/100 g)	FRAP assay (µmol Fe2+/100 g)
‘G-2-22’	245.2 ± 8.2 e	105.7 ± 1.6 f	103.4 ± 3.2 d	4507.1 ± 153.9 e
‘G-3-3’	359.9 ± 8.2 c	122.0 ± 2.3 cde	163. 9 ± 1.7 c	5405.3 ± 47.5 de
‘G-3-4’	422.7 ± 16.6 b	149.5 ± 1.5 b	236.1 ± 4.3 b	8256.3 ± 135.7 bc
‘G-5-25’	438.6 ± 21.8 ab	127.2 ± 3.4 cd	216.1 ± 5.1 b	7898.5 ± 337.8 c
Felama®	299.1 ± 8.7 de	133.3 ± 2.0 c	157.1 ± 6.7 c	5817.5 ± 79.4 d
Isabelona®	424.9 ± 10.2 b	156.0 ± 2.2 ab	281.3 ± 11.1 a	9077.5 ± 320.1 ab
Mardía®	307.9 ± 12.9 cd	113.3 ± 2.0 ef	154.8 ± 3.9 c	5406.2 ± 100.4 de
‘Guara’	486.8 ± 4.7 a	151.7 ± 2.2 b	240.3 ± 9.4 b	9137.3 ± 77.6 ab
Soleta®	324.7 ± 6.4 cd	112.3 ± 4.9 ef	153.9 ± 1.3 c	5791.9 ± 187.5 d
Vairo®	317.9 ± 2.4 cd	118.3 ± 2.2 def	169.1 ± 0.8 c	5959.9 ± 82.7 d
Vialfas®	476.4 ± 19.9 ab	168.1 ± 3.3 a	286.6 ± 8.0 a	9785.4 ± 178.1 a

FRAP = ferric-reducing ability of plasma.

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Table 4. Oil and fatty acid composition of each genotype studied in Kodad and R Socias i Company et al. (2008).

	Oil content		Palmitic		Palmitoleic		Stearic		Oleic		Linpleic		O/L[iii]	
Genotype	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003
A-10–6	55.2	56.5	6.3	5.3[ii]	0.6	0.5	2.3	2.2	70.3	76.9[ii]	19.4	15.4[ii]	3.6	4.9[ii]
Cambra	63.8	64.5	6	5.7	0.7	0.7	1.6	1.9	77.8	76.5	12.7	13.2	6.1	5.8
Soleta	63.8	62.4	6	6.3	0.7	0.6	1.2	2.3[ii]	74.8	70.7[ii]	15.7	17.4	4.9	4.1
Felisia	56.3	55.5	6.5	5.4[ii]	0.7	0.6	2.3	1.6[ii]	68.1	75.5[ii]	22.1	16.7[ii]	3.1	4.5[ii]
Ferragnès	57.7	62.9[ii]	6.6	5.4	0.5	0.4	1.8	2.1	70.4	76.7[ii]	20.3	15.1[ii]	3.4	5.1[ii]
Guara	54.3	55.8	6.7	7.1	0.4	0.4	2.8	1.8	63.1	63.4	25.7	27.1	2.5	2.4
Bertina	56.7	56.2	6.3	5[ii]	0.5	0.3[ii]	2.5	2.1	69.2	69.9	21.1	22.3	3.2	3.1
Moncayo	57.1	57.5[ii]	5.9	5.1	0.5	0.4	2.1	2	74.8	75.5	16.3	16.7	4.6	4.5
Marcona	59.8	58.4	6.3	5.9	0.5	0.6	1.8	2.1	71.4	72.1	19.7	19.1	3.6	3.7
D. Largueta	59.1	55.6	6.1	6.9	0.4	0.4	1.8	1.8	72.4	68.9[ii]	18.8	22.3[ii]	3.8	3.1
G-1-1	61.4	60.8	5.6	6	0.5	0.5	2.4	2.5	75.3	75.3	15.7	15.4	4.8	4.9
G-1-23	62.3	60.9[ii]	5.5	5	0.5	0.3[ii]	2.3	2.1	73.9	75.7	16.6	16.6	4.5	4.6
G-1-27	58.7	58.7	5.9	6.1	0.4	0.4	2	2	71.1	70.9	19.4	19.3	3.7	3.6
G-1-38	56.9	52.8[ii]	5.9	6.7	0.6	0.7	2	1.6	72.8	69.9	19	20.6	3.9	3.4
G-1-41	67.5	59.4[ii]	5.7	5.2	0.5	0.4	2	1.7	74.4	77.4[ii]	16.8	14.8[ii]	4.4	5.2[ii]
G-1-58	57.2	56	6.1	6.3	0.6	0.6	1.7	1.6	75.5	75.5	15.5	15.8	4.9	4.8
G-1-61	61.3	59.5[ii]	6.5	5.9	0.5	0.5	2.3	1.5[ii]	74.7	73.6	16.9	18.9	4.4	3.9
G-1-64	58.9	59.2	6.2	6.3	0.4	0.3	2.1	2	74	71.0[ii]	17.1	19.5[ii]	4.4	3.6[ii]
G-1-67	54.2	57.5[ii]	6.4	6.1	0.6	0.5	1.6	1.7	69.8	71.5	20.6	19.6	3.4	3.7
G-2-1	60.9	56.4[ii]	6.4	5.7[ii]	0.5	0.4	1.9	1.8	67.5	66.9	24.1	24.9	2.8	2.7
G-2-11	58.6	57.3	6.5	6.5	0.6	0.6	1.6	1.3	68.9	70.3[ii]	21.8	20.8	3.2	3.4
G-2-2	58.9	58.4	5.9	5.5	0.6	0.5	2	2.2	73	71.8	18.8	19.6	3.9	3.7
G-2-22	55.1	56.4	6.1	6.2	0.5	0.5	1.7	1.3	75.8	75.8	15.6	15.6	4.9	4.9
G-2-23	53.5	58.6[ii]	5.8	5.7	0.7	0.7	1.4	1.4	72.1	73.4	18.8	18.5	3.8	4
G-2-25	60.3	57.9	5.5	5.8	0.5	0.5	2.3	2	75.6	74.3	16	17.1	4.7	4.4
G-2-26	59	65.0[ii]	6.2	5.8	0.5	0.5	1.8	1.9	72.4	74.5	18.8	16.6	3.9	4.5[ii]
G-2-27	55.7	58.3[ii]	6.9	7	0.7	0.7	1.7	1.5	70.1	74.4[ii]	16.8	15.9	4.2	4.7
G-2-7	58.8	59.3	6.5	6.6	0.6	0.6	1.7	1.7	69.7	68.2	21.1	22.4	3.3	3.1
G-3-12	62.7	61.5	6.2	6.3	0.5	0.5	1.8	2.1	71.1	69.3	20.1	21.6	3.5	3.2
G-3-24	55.4	60.0[ii]	6.3	6.1	0.7	0.6	1.4	1.5	71.4	73.1	20.6	18.5	3.5	4
G-3-28	65.1	56.2[ii]	6.2	6.5	0.5	0.6	2	1.8	71.2	71.5	19.6	18.5	3.6	3.9
G-3-3	55.6	53.4	6.2	6.3	0.8	0.7	2.1	2.2	72	70.5	18.3	19.3	4	3.7
G-3-4	57.5	55.7	5.8	5.6	0.5	0.5	1.7	1.7	67	65.7	23	25.2[ii]	2.9	2.6
G-3-5	58.6	60.6	5.7	5.9	0.5	0.6	2.3	2.5	75	78.7[ii]	16.5	12.1[ii]	4.6	6.6[ii]
G-3-65	56.2	48.3[ii]	6	6	0.6	0.6	2	1.9	73.5	73	17.4	18.1	4.2	4
G-3-8	53.6	53	6.2	6.2	0.6	0.4[ii]	1.7	1.1[ii]	76.6	71.4[ii]	15.5	19.8[ii]	5	3.6[ii]
G-4-10	61.6	58.7	5.8	5.4	0.5	0.4	2.1	1.9	75.4	78.1	15.3	13.8	5	5.7
G-4-3	61.8	54.2[ii]	6.5	6.6	0.6	0.5	1.5	1.2	68.9	68.2	22	23.1	3.1	3
G-5-18	51.8	64.1[ii]	6.5	6.2	0.5	0.5	2	1.8	71.1	72.5	19.2	18.6	3.7	3.9
G-5-2	54.1	53.5	5.9	6.1	0.4	0.5	2.3	1.4[ii]	74.1	77.0[ii]	17	14.3[ii]	4.4	5.4[ii]
G-5-25	59	60.1	5.9	6	0.6	0.5	1.8	1.7	73.2	71.5	17.1	19.4	4.3	3.7
G-6-14	56.9	58.4	5.4	5.5	0.4	0.4	1.5	1.5	75.1	76.7	14.9	15.7	5.1	4.9
G-6-24	58.5	56.2	6.6	6.7	0.6	0.6	2	2.4	69.7	69.2	20.3	20.4	3.4	3.4
G-6-39	57.3	60.0[ii]	5.6	5.5	0.5	0.5	1.6	1.5	76.4	77.2	14.9	15	5.1	5.2
H-1-108	54.6	51.3	6	5.9	0.5	0.5	1.9	2.1	71.2	69.9	20.2	20.6	3.5	3.4
H-1-81	55.9	62.6[ii]	5.4	5.7	0.5	0.5	2	2	76.4	76.9	15	14.4	5.1	5.3
H-2-111	58.1	59.7	5.8	6	0.6	0.6	1.8	1.8	76	76.5	15.1	14.5	5	5.3
H-3-37	60.3	63.2[ii]	5.5	6.0[ii]	0.6	0.6	1.7	1.7	76.1	77.4	15.2	14	5	5.6
H-3-39	60	61.5	5.9	5.5	0.5	0.5	1.7	2.2	75.6	76.5	17.1	15.2	4.4	5.1[ii]
I-1-95	57	63.4[ii]	6.4	6.6	0.5	0.5	2.5	1.7[ii]	73.1	71.1	17.6	19.2	4.2	3.7
I-2-12	57	60.8[ii]	6	5.9	0.5	0.5	2	1.8	70.9	72.1	19.5	19.4	3.6	3.7
I-3-10	56.8	56.9	6.5	6.7	0.5	0.5	2.1	2.1	71.8	71.3	18.3	18.5	3.9	3.9
I-3-11	54.9	54.6	6.1	6.3	0.6	0.6	1.9	1.9	74.8	75.1	16.8	15.9	4.5	4.7
I-3-27	56.2	58.5	5.7	5.8	0.6	0.6	2.3	2.7	78	78.1	12.2	12.5	6.4	6.2
I-3-65	50.7	53.0[ii]	6.5	6.6	0.5	0.5	1.5	1.7	70.6	71	18.5	19.2	3.8	3.7
I-3-67 (Felama®)	56.9	59.4	5.6	6.1[ii]	0.5	0.5	2.4	2.4	73.9	71.7	17.7	19	4.2	3.8

[i] Oil content is given as percentage of kernel dry weight; fatty acid composition is given as percentage of total oil content.
[ii] Significant difference at $P < 0.01$ between the yearly means of each component for every genotype.
[iii] The O/L factor means the ratio of oleic acid (O) to linoleic acid (L) of the tested vegetable oil. This ratio is employed in making assessments of quality of oil. In essence, higher O/L value means more oxidative stability since oleic acid is more resistant to oxidation than linoleic acid and therefore better oil quality.

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