'Santaclara' Strawberry

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Since 2000, the high significance of strawberry (*Fragaria ×ananassa* Duch.) production in Huelva, located on the southwest coast of Spain, has led public and private institutions to increase the releasing of new cultivars that are well adapted to the climate characteristics and growing conditions in Huelva and other mild areas. The Spanish public breeding program has contributed to this effort with cultivars such as 'Andana', 'Carisma', 'Marina', 'Medina', 'Aguedilla', and 'Fuentepina' (Bartual et al., 1997, 2002; López-Aranda et al., 2004, 2005a, 2005b; Soria et al., 2010).

'Santaclara' is a new short-day cultivar recently released by the Spanish public breeding program, participating in the Spanish National Agricultural Research Institute (INIA), the Andalusian Institute of Agriculture and Fishery Research and Training (IFAPA) as well as the private partners Fresas Nuevos Materiales S.A. (FNM), Freshuelva Viveristas (FV), and Nuevas Técnicas de Fresa S.L. (NTF). The main purpose of this program is to breed cultivars for high yield, large fruit size for the fresh market, and high fruit quality and which outperform currently grown short-day cultivars in mild climate areas (e.g., 'Camarosa').

'Santaclara' is noted for its medium- to high-balanced agronomic, postharvest, and fruit quality traits (including nutraceutic values). 'Santaclara' also shows excellent comparative qualities for the fresh market and adapts well to mild agroenvironments.

This new cultivar was named after an old monastery founded in 1337 and located at Moguer (Huelva), place of birth of the 1965 Nobel prize awarded poet Juan Ramón Jiménez, who spent his youth in the strawberry production area around this nice village.

Origin

'Santaclara' was selected from a 2004 cross between the breeding line 1084-1 ('Carisma' × 'Plasirfre') and 'Ventana'; this cross (Fig. 1)

was made at IFAPA (Churriana, Málaga) and was tested as selection 2340-1 in 2005 at the IFAPA production field (Moguer, Huelva). The female parent 1084-1 is a short-day cultivar with excellent fruit appearance identified in previous field tests. 'Ventana' (Larson and Shaw, 2001) is a short-day accession chosen as the male parent as a result of its high precocity and total yield production with large to very large firm fruits. Both parents are very well adapted to the growing conditions of Huelva.

From 2005, 'Santaclara' was propagated every season for performance evaluations at high-elevation nurseries in northeastern Spain (Castilla-León; Arevalo-Avila, altitude 900 to 1100 m). Runner-propagated plants were evaluated from 2006 to 2010, along with other well-adapted cultivars, in replicated plot trials in an experimental field near the area of Moguer (Huelva).

Description

'Santaclara' is described subsequently following the International Union for the Protection of New Varieties of Plants (UPOV)

guidelines (UPOV, 1995), and differences with 'Camarosa', when exist, are shown.

'Santaclara' is a short-day strawberry cultivar. Plant vigor is medium with a globose growth habit. When planted in high-elevation nurseries in mid-April, plants tend to produce many runners with very low anthocyanin coloration and medium pubescence. Leaves are strongly to slightly concave and medium blistering with three dark green medium-glossy leaflets; in contrast to the weak blistering, medium green leaflets of 'Camarosa'. The terminal leaflet is longer than wide with an obtuse base and crenate margins, whereas the terminal leaflet of 'Camarosa' is as long as wide.

Inflorescences are located at the end of long peduncles and flowers open at the level of the canopy. Flower size is medium and the calyx diameter is higher than the corolla. The corolla has five overlapping white petals that are broader than longer in contrast to 'Camarosa' that shows as long as broad touching petals. The conical berries are large, much longer than broader (Fig. 2), with medium red flesh and external color. The internal cavity is either small or medium expressed. The fruit surface is even, achenes are inserted leveled with the surface, and the band without achenes is absent or very narrow; 'Camarosa' fruit surface is darker and slightly uneven with achenes inserted below the surface. The calyx of 'Santaclara' is firmly attached to the fruit with a slightly larger diameter. The fruit flesh is very firm, pleasantly aromatic, and tasty.

Early and total yields for 'Santaclara' are similar to those of standard cultivars grown in southwestern Spain such as 'Camarosa' and 'Sabrosa' (Table 1). Post-harvest tests showed that 'Santaclara' has a good shelf life, similar to that of 'Camarosa' and 'Sabrosa' and longer than that of 'Aguedilla' and 'Ventana' (Table 3). The best attributes of 'Santaclara'

Fig. 1. Pedigree of 'Santaclara' strawberry.

Fig. 2. Fruits of 'Santaclara' strawberry.

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are its remarkably high fruit firmness and a very high ascorbic acid content (vitamin C) (Table 4).

Genetic characterization of 'Santaclara' (Gil-Ariza et al., 2006) using three micro-satellites yielded the following patterns: ChFaM001: 244, 231, 212; ChFaM002: 174, 164; and ChFaM004: 187, 173, 147, 145, 137.

Performance

During the 2008, 2009, and 2010 seasons, 'Santaclara' fruit yield (Table 1), fruit quality (Table 2), and shelf life traits (Table 3) were assessed and compared with several well-adapted short-day cultivars: 'Camarosa', 'Ventana', 'Aguedilla', 'Amiga', 'Fuentepina',

'Sabrosa', 'Splendor', 'Florida Fortuna' (named 'Florida Radiance' in USA), 'Primoris', and 'Antilla'. Throughout those 3 years, cultivar performance was evaluated in experimental fields in the strawberry production area of Moguer (Huelva).

To reduce the presence of soilborne pathogens, an experimental plot soil was solarized and biofumigated each year (Medina et al., 2009) before planting.

During the third week of October of each year (2008, 2009, and 2010), plants were planted in three completely randomized plots of 50 plants each on two-row raised beds covered with black plastic and drip irrigation pipes under the plastic. Plants were spaced 0.25×0.25 m apart. In mid-November plants were covered with large plastic (150 μ m) tunnels (6.6 m wide $\times$ 3.5 m high $\times$ 70 m long). Between mid-November and mid-May, the fertilizer rate was: 175 kg N/ha, 77 kg P_2O_5 /ha, 185 kg K_2O /ha, 85 kg CaO/ha, and 14 kg MgO/ha. Marketable fruits (first-plus second-quality fruits; no misshapen fruits of 17 g or greater and between 10 and 17 g, respectively) were harvested and weighed once or twice a week from early January to late May.

Fruit weight was calculated by weighing 20 first-quality fruits eight times throughout the season and dividing total weight by the number of harvested fruits (160). Three times per season (mid-February, mid-March, and mid-May), six randomly chosen fruits per plot were evaluated for quality traits such as external and internal color, internal cavity size, firmness, and soluble solid content and

Table 1. Fruit yield of 'Santaclara' versus standard strawberry cultivars grown at Huelva (Spain) during 2008, 2009, and 2010 seasons.

Cultivar	Early yield ^a		Total yield		Fruit wt (g/fruit)
	Marketable (g/plant)	Second quality (%)	Marketable (g/plant)	Second quality (%)	
2008					
Santaclara	585 ab ^y	9.5 b	1007 b	11.6 b	26.0 bc
Camarosa	528 bc	15.4 a	996 b	17.1 a	25.1 c
Ventana	632 a	6.3 c	1079 ab	11.3 b	25.4 bc
Aguedilla	624 a	4.3 d	1163 a	9.1 bc	31.7 a
Amiga	446 cd	1.9 e	1072 ab	8.1 c	27.7 b
Fuentepina	427 d	6.7 c	728 c	7.6 c	25.5 bc
2009					
Santaclara	340 ab	10.4 ab	781 a	11.7 b	25.8 c
Camarosa	387 a	12.8 a	832 a	17.1 a	26.7 c
Sabrosa	239 c	5.9 bc	717 ab	12.2 b	25.0 c
Aguedilla	384 a	6.4 bc	882 a	11.6 b	32.1 a
Fuentepina	266 bc	3.4 c	563 b	6.2 c	29.1 b
2010					
Santaclara	289 bc	9.8 abc	831 b	10.6 b	24.4 c
Camarosa	269 c	11.0 a	807 b	14.2 a	25.7 bc
Sabrosa	288 bc	6.1 de	803 bc	11.6 b	25.0 bc
Splendor	341 a	8.3 bc	912 a	11.5 b	26.7 ab
F. Fortuna	287 bc	8.1 cd	689 d	9.6 b	25.3 bc
Primoris	310 ab	10.0 ab	866 ab	14.4 a	24.2 c
Antilla	261 c	3.5 f	708 d	7.1 c	28.4 a
Fuentepina	314 ab	4.2 ef	735 cd	5.6 c	25.7 bc

^aEarly yield: up to the end of March.

^yMean values in each column followed by different letters are significantly different at $P \leq 0.05$ as determined by Fisher's least significant difference test.

Table 2. Comparison of fruit quality traits of 'Santaclara' versus standard strawberry cultivars grown at Huelva (Spain) during the 2008, 2009, and 2010 seasons.

Cultivar	External color ^a	Internal color ^a	Internal cavity size ^y	Firmness (g of pressure)	Total sugar content (°Brix)
2008					
Santaclara	5.7 abc ^x	4.8 ab ^x	4.8 ab ^x	375 b ^w	7.4 c ^w
Camarosa	6.6 a	5.4 a	5.0 a	357 c	7.9 b
Ventana	6.0 ab	5.0 a	4.1 ab	325 d	7.1 cd
Aguedilla	6.3 a	5.0 a	5.9 a	313 d	6.8 d
Amiga	4.9 bc	5.0 a	4.6 ab	443 a	6.7 d
Fuentepina	4.8 c	3.0 b	3.2 b	350 c	8.4 a
2009					
Santaclara	5.9 b	4.8 ab	3.4 b	387 a	7.7 bc
Camarosa	7.0 a	5.9 a	4.6 ab	347 c	8.1 ab
Sabrosa	6.0 ab	5.0 ab	4.3 ab	374 ab	8.6 a
Aguedilla	6.3 ab	5.9 a	5.2 a	322 d	7.5 c
Fuentepina	5.2 b	3.9 b	3.0 b	364 bc	8.3 a
2010					
Santaclara	5.8 ab	4.8 abc	3.9 ab	444 a	6.9 cd
Camarosa	6.1 a	6.1 a	4.0 ab	387 d	6.6 d
Sabrosa	5.2 bc	4.9 abc	3.7 ab	412 c	7.3 abc
Splendor	6.2 a	5.9 a	4.4 a	321 e	5.9 e
F. Fortuna	5.7 ab	5.3 ab	3.2 b	374 d	6.9 bcd
Primoris	4.7 c	4.9 abc	3.2 b	440 ab	7.7 a
Antilla	5.4 abc	4.0 bc	3.8 ab	430 b	7.4 ab
Fuentepina	4.4 c	3.7 c	3.1 b	386 d	6.7 d

^aRated on a scale from 3 to 7, where 3 = light red and 7 = deep red.

^yRated on a scale from 3 to 7, where 3 = absent and 7 = large internal cavity along the fruit.

^wWithin columns, mean values followed by different letters are significantly different at $P \leq 0.05$ as determined by the Kruskal-Wallis comparison test.

^xWithin columns, mean values followed by different letters are significantly different at $P \leq 0.05$ as determined by Fisher's least significant difference test.

Table 3. Shelf life parameters of 'Santaclara' and other strawberry cultivars grown in Huelva, Spain, during the 2008, 2009, and 2010 crop seasons.

Cultivar	Calyx freshness ^a	Bruising ^y
2008		
Santaclara	5.2 ab ^x	6.2 ab
Camarosa	5.2 ab	5.8 abc
Ventana	4.0 b	4.7 bc
Aguedilla	4.7 ab	4.3 c
Amiga	4.5 b	7.0 a
Fuentepina	6.2 a	6.7 a
2009		
Santaclara	6.0 a	5.0 ab
Camarosa	6.7 a	5.3 ab
Sabrosa	6.7 a	6.3 a
Aguedilla	5.2 a	3.7 b
Fuentepina	6.3 a	5.5 a
2010		
Santaclara	4.8 abc	6.0 a
Camarosa	4.4 bc	6.0 a
Sabrosa	5.1 abc	6.3 a
Splendor	5.5 ab	5.8 a
F. Fortuna	3.8 c	6.1 a
Primoris	5.8 a	6.8 a
Antilla	5.7 ab	6.7 a
Fuentepina	5.3 ab	5.9 a

^aRated on a scale from 3 to 7, where 3 = low calyx freshness and 7 = high calyx freshness.

^yRated on a scale from 3 to 7, where 3 = highly bruised and 7 = not bruised.

^xWithin columns, mean values followed by different letters are significantly different at $P \leq 0.05$ as determined by the Kruskal-Wallis comparison test.

only twice (mid-February and mid-May) for acidity. Color and cavity size were subjectively rated on a visual scale (Table 2). Fruit firmness was determined using a penetrometer with a 3.5-mm tip, soluble solid content was measured using a refractometer (Domínguez et al., 2004), and acidity by an automatic titration unit; results were expressed as grams citric acid per 100 g of fresh weight. To estimate the shelf life of 'Santacalara' fruits and compare it with the other cultivars, three times during the season, 500 g of randomly chosen ripe fruits per plot were maintained under controlled temperature (4 °C) in a refrigerated chamber during 3 d followed by 2 d at room temperature; then calyx freshness and resistance to bruising were evaluated. Each trait was rated on a scale from 3 to 7, in which 3 is low calyx freshness and high bruising and 7 is high calyx freshness and not bruising (Table 3).

During the 2009 season, nutraceutical traits (Table 4) on 'Santacalara' fruits were compared with those of 'Camarosa', 'Aguedilla', 'Fuentepina', and 'Sabrosa'. For the determination of nutraceutical compounds content, two assessments were run along the growing season: in mid-February and mid-April. Each time, a 250-g sample of randomly chosen ripe fruit per replication and plot was homogenized and stored at -20 °C. Total soluble phenolic compounds were measured in frozen samples using the Folin-Ciocalteu reagent (Slinkard and Singleton, 1977) and expressed as milligrams of gallic acid equivalent (GAE) per 100 g fresh weight. Total flavonoid content was measured by the aluminium chloride colorimetric assay (Dewanto et al., 2002) and expressed as milligrams of catechin equivalent (CE) per 100 g fresh weight. Total anthocyanins were determined following the procedure of Cheng and Breen (1991) and expressed as milligrams of pelargonidin-3 glucoside equivalent (Pg-3-gluc) per 100 g fresh weight. Total ascorbic acid was measured with reflectometric test strips (Reflectoquant; Merck, Darmstadt, Germany) and expressed as milligrams per 100 g fresh weight.

A variance analysis was applied to the recorded data using Statistix 8.0 software (Analytical Software, Tallahassee, FL) and mean values were compared at the 0.05 level using Fisher's least significant difference test or the Kruskal-Wallis test (for subjective data).

The percentage of second-quality fruit was arcsine-transformed before analysis.

Results for 'Santacalara' yield, fruit quality, and shelf life traits are provided in Tables 1, 2, and 3. Early and total fruit yields of 'Santacalara' were similar to those of 'Camarosa' and 'Sabrosa' in the three growing seasons; however, 'Camarosa' produced a higher early and total percentage of second-quality fruit in most years (Table 1). 'Aguedilla' in 2008 and 'Splendor' in 2010 produced higher yields than 'Santacalara'. In general, early and total percentage of second-quality fruit of 'Santacalara' is intermediate (ranging between 9% and 12% of marketable production). The average fruit size of 'Santacalara' was significantly smaller than 'Aguedilla' fruits in 2008 and 2009 and than 'Antilla' fruits in 2010 but was similar to that of the other cultivars, ranging between 24.4 and 26.0 g.

Overall, higher values of yield (early and total yield) were obtained in 2008, which could be related to the optimal meteorological conditions recorded during that year in contrast to the low temperatures of 2009 and the excessive rainfall of 2010 (IFAPA, 2011).

The color of fully mature 'Santacalara' fruits was intermediate red both on the outside and the inside (Table 2). External color of 'Aguedilla', 'Ventana', 'Camarosa', and 'Splendor' was darker and 'Amiga', 'Fuentepina', and 'Primoris' was lighter than 'Santacalara' fruits.

The internal cavity was weakly to medium expressed and, in general, similar to that recorded for the other cultivars. 'Santacalara' fruit firmness ranged from 375 to 444 g pressure, values higher than those recorded for the majority of cultivars. Only 'Amiga' (443 g pressure in 2008) showed higher firmness than 'Santacalara'. Fruits of 'Santacalara' are tasteful and their soluble solid content ranged from 6.9 to 7.7 °Brix; these values were similar to those of 'Camarosa' and 'Florida Fortuna' but lower than those of 'Fuentepina', 'Sabrosa', 'Primoris', and 'Antilla' and significantly higher than those of 'Aguedilla', 'Amiga', and 'Splendor' (Table 2).

'Santacalara' fruits showed good shelf life. Calyx freshness and resistance to bruising were similar to that of 'Camarosa', 'Amiga', 'Fuentepina', 'Sabrosa', 'Splendor', 'Primoris', and 'Antilla' fruits but higher than that of

'Aguedilla', 'Ventana', and 'Florida Fortuna' fruits (Table 3).

During the 2009 season, nutraceutical traits (Table 4) for 'Santacalara' fruits were assessed and compared with values of 'Camarosa', 'Sabrosa', 'Aguedilla', and 'Fuentepina' fruits. Total phenolic content of 'Santacalara' fruits was 110 mg GAE per 100 g fresh weight, similar to those recorded for the other cultivars. Total anthocyanin content reached 13.5 mg Pg-3-gluc per 100 g fresh weight, which was similar to that of 'Camarosa' and 'Aguedilla' and higher than that of 'Sabrosa' and 'Fuentepina'. 'Santacalara' fruits showed the lowest flavonoid content with 8.8 mg CE per 100 g fresh weight. However, it is very important to point out that 'Santacalara' fruits had higher ascorbic acid content, 59.7 mg per 100 g fresh weight, significantly higher than any of the other tested cultivars.

Plants of 'Santacalara' and 'Camarosa' were inoculated artificially in the laboratory with *Xanthomonas fragariae* Kennedy & King, *Phytophthora cactorum* (Lebert & Cohn), *Verticillium dahliae* Kleb., and *Podosphaera aphanis* (Wallr.); the latter was also evaluated under field conditions. The resistance of 'Santacalara' to *X. fragariae* was greater than that observed for 'Camarosa'; the resistance to *P. cactorum* was similar; however, resistance to *P. aphanis* and *V. dahliae* was less than that of 'Camarosa' (De Cal, personal communication).

As a summary, the strengths of this new cultivar are its balanced agronomic and nutraceutical characteristics such as high early and total yields, large fruits and high fruit firmness, low percentage of misshapen fruits, and high ascorbic acid content. On the other hand, the weakness of 'Santacalara' is a medium to high percentage of second-class fruits (Table 1), mainly in early plantings.

Availability

The Andalusian Government (IFAPA-Junta de Andalucía), INIA, FNM, NTF, and FV have jointly applied for the inscription of 'Santacalara' in the Register of Commercial Strawberry Varieties (Spanish Plant Variety Office, application number 20090247).

Third parties interested in the propagation and/or commercial use of this cultivar should contact the authors of this article. E-mail: josem.lopez.aranda@juntadeandalucia.es.

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Table 4. Comparison of nutraceutical compounds content on 'Santacalara' fruits versus standard strawberry cultivars grown at Huelva (Spain) during the 2009 season.

Cultivar	Phenolics compounds ^a	Flavonoids ^b	Anthocyanins ^c	Ascorbic acid ^w	Titrateable acidity ^v
Santacalara	110.0 a ^u	8.8 d	13.5 a	59.7 a	0.72 c
Camarosa	130.9 a	12.7 b	15.2 a	47.2 b	0.88 a
Sabrosa	111.2 a	12.5 b	10.3 b	48.7 b	0.78 b
Aguedilla	117.9 a	18.3 a	13.1 a	50.7 b	0.89 a
Fuentepina	104.3 a	11.3 c	7.9 b	44.8 b	0.59 d

^aExpressed as milligrams of gallic acid equivalent/100 g fresh fruit.

^bExpressed as milligrams of catechin equivalent/100 g fresh fruit.

^cExpressed as milligrams of pelargonidin-3-glucoside/100 g fresh fruit.

^wExpressed as milligrams of ascorbic acid/100 g fresh fruit.

^vExpressed as grams citric acid/100 g fresh weight.

^uWithin columns, mean values followed by different letters are significantly different at $P \leq 0.05$ as determined by Fisher's least significant difference test.

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