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‘UC Surfline’, a Short-day Strawberry Cultivar with High Early and Sustained Yields

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The winter production of strawberries (*Fragaria* ×*ananassa*) in western North America, the southeastern United States, and many other parts of the world has traditionally been dominated by short-day cultivars, partly because they bear fruit earlier in the season than day-neutral cultivars (López-Aranda et al. 2011). The short-day segment in western North America, however, faces economic pressure in the late spring as the volume of early season fruit from the day-neutral segment reaches the marketplace. That marketplace dynamic highlights the importance of short-day cultivars that deliver high yields early in the season in California and Mexico when fruit volumes are lower. Similar economic pressures occur in Florida, where early season yields of short-day cultivars are critical (Whitaker and Fan 2020).

Over the last two decades, the short-day segment in California and Mexico has also faced increased economic pressure from diseases caused by soilborne pathogens, particularly Fusarium wilt, Verticillium wilt, Phytophthora crown rot, and Macrophomina crown rot (Dilla-Ermita et al. 2023; Koike 2008; Koike et al. 2009, 2013; Mertely et al. 2005; Njoroge et al. 2009; Paulus 1990; Subbarao et al. 2007). The yield losses from those diseases and others can be substantial and underscore the importance of improving resistance through breeding, a critical line of defense.

We initiated genetic studies in 2015 to identify solutions to several disease-resistance breeding problems in strawberry. There was a particularly urgent need to develop insights into the genetics of resistance to Fusarium wilt, a disease that was first reported in California only one decade earlier and has since wreaked havoc throughout California (Koike et al. 2009, 2013). Little was known about the genetics of resistance to Fusarium wilt when our studies were undertaken; however, the discovery of gene-for-gene resistance accelerated the development of Fusarium wilt–resistant cultivars through phenotypic and marker-assisted selection, which includes ‘UC Surfline’ and ‘UC Monarch’ (Cole et al. 2025; Pincot et al. 2018, 2022).

We initially faced the problem that the genomic resources needed to delve into the genetics of resistance using octoploid genome–informed approaches had not yet been developed. Those barriers were quickly overcome with the development of octoploid reference genomes and high-throughput, octoploid genome–anchored genotyping platforms (Edger et al. 2019; Hardigan et al. 2020, 2021, 2023; Whitaker et al. 2020; https://phytozome-next.jgi.doe.gov/info/FxananassaRoyalRoyce_v1_0). Those genomic resources were developed in parallel with the development of disease-resistance screening protocols and phenotypic databases critical for identifying sources of resistance and implementing genome-informed breeding solutions (Feldmann et al. 2024; Jiménez et al. 2023; Knapp et al. 2024; Pincot et al. 2018, 2020, 2022). Our studies and others in the intervening decade greatly expanded our understanding of the genetics of resistance to diseases caused by soilborne pathogens, identified numerous sources of favorable alleles for improving resistance, and empowered genome-informed approaches for accelerating the development of disease-resistant cultivars (Feldmann et al. 2024; Jiménez et al. 2023; Mangandi et al. 2017; Noh et al. 2018; Pincot et al. 2018, 2020, 2022; Whitaker et al. 2020). ‘UC Surfline’ was one of the hybrid individuals to emerge from our initial cycle of selection that was highly resistant to Fusarium wilt, Verticillium wilt, and Phytophthora crown rot, in addition to producing high early fruit yields.

Here, we describe the origin and attributes of ‘UC Surfline’, a short-day strawberry cultivar with high early and sustained fruit yields that exceed those of short-day cultivars widely grown in western North America, from central Mexico to the central coast of California. ‘UC Surfline’ was released by the College of Agriculture and Environmental Sciences at the University of California (UC), Davis in 2023 in parallel with ‘UC Monarch’, a short-day cultivar described in a companion paper (Cole et al. 2025). ‘UC Surfline’ produces large, firm, long-shelf-life fruit. Importantly, the firmness of ‘UC Surfline’ fruit has been consistently superior to check cultivars late in the season when rising temperatures tend to negatively affect fruit firmness and marketability. The plant health and productivity of ‘UC Surfline’ can be partly attributed to a strong disease-resistance package.

Origin

‘UC Surfline’ is a hybrid individual from a full-sib family (16C555) developed by hybridizing 07C148P001 and 10C037P604 in Winter 2015–16. This cultivar was internally and externally tested as 16C555P053. The parents of this hybrid are unreleased hybrid individuals preserved in the UC Davis clonal germplasm repository. ‘UC Surfline’ was one of 10,000 thousand seed–propagated hybrid individuals from 121 full-sib families that were evaluated at the UC Davis Wolfskill Experiment Orchard, Winters, CA, USA, in 2016–17. These individuals were phenotyped in the spring of 2017 in Winters, CA, to identify individuals with outstanding fruit size, firmness, flavor, symmetry, color, gloss, and visual appeal; eliminate individuals with fruit defects and deformities; and assess marketable fruit yield, photoperiod sensitivity, and runner production. ‘UC Surfline’ was one of 112 hybrid individuals selected in 2017 for advanced testing in Oxnard and Santa Maria, CA, USA, and disease resistance screening at the UC Davis Armstrong Plant Pathology Farm in Davis, CA, USA. Clones of ‘UC Surfline’ were initially propagated from a single mother plant in 2016–17. ‘UC Surfline’ has since been preserved by annual cycles of asexual propagation in Winters, CA, USA.

Clones (asexually propagated bare-root plants) of ‘UC Surfline’, check cultivars, and other individuals selected for advanced testing in 2019–20, 2020–21, and 2021–22 were produced in commercial high-elevation nurseries (Cedar Point, Dorris, CA) using standard production and propagation practices and postharvest chilling treatments optimized for the short-day market segment. Clones were harvested in September, trimmed, and directly planted in October of each year with minimal additional chilling. We completed three seasons of advanced testing of ‘UC Surfline’, two short-day check cultivars (Fronteras and UCD Victor), and other short-day hybrid individuals (advanced selections) on farms in Oxnard and Santa Maria, CA, USA, to support the release of this cultivar (Tables 1–4; Figs. 1–3). The statistics reported here were estimated from full-season harvests of fruit in the 2019–20, 2020–21, and 2021–22 short-day growing seasons on those farms (Tables 1–3; Figs. 2 and 3) and from disease-resistance screening studies conducted over the 2019–20, 2020–21, and 2021–22 growing seasons in Davis, CA (Table 4).

‘UC Surfline’, check cultivars, and other hybrid individuals were grown in two 12-plant plots in 2019–20 and two 24-plant plots in 2020–21 and 2021–22. The plots were arranged in randomized complete block experiment designs. These yield trials were grown using the management practices, bed

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Table 1. Across-environment estimated marginal means (EMMs) for cumulative marketable fruit yield, weight, and quality traits for 'UC Surfline' and check cultivars grown on commercial farms in Oxnard and Santa Maria, CA, USA, over three growing seasons (2019–20, 2020–21, and 2021–22).

Trait[i]	Cultivar	EMM	t[ii]	P value[iii]
Early yield (kg/ha)[iv]	UC Surfline	7,154		
	Fronteras	5,979	1.75	0.10
	UCD Victor	2,691	6.15	<0.0001
Yield (kg/ha)	UC Surfline	52,532		
	Fronteras	43,526	2.18	0.05
	UCD Victor	45,814	1.51	0.15
Size (g/fruit)	UC Surfline	29.5		
	Fronteras	32.4	−2.61	0.03
	UCD Victor	29.6	−0.07	0.94
Firmness (g-force)	UC Surfline	339.1		
	Fronteras	225.9	3.44	0.001
	UCD Victor	296.5	1.64	0.11
TSS (%)	UC Surfline	8.18		
	Fronteras	8.67	−1.25	0.22
	UCD Victor	7.89	0.97	0.34
TA (%)	UC Surfline	0.86		
	Fronteras	0.86	0.11	0.91
	UCD Victor	0.76	2.93	0.005
TSS/TA	UC Surfline	9.82		
	Fronteras	10.44	−0.87	0.39
	UCD Victor	10.47	−1.15	0.26

[i]Cumulative marketable fruit yields were estimated from fruit harvested on commercial schedules (once or twice weekly) over the entire short-day growing season on each farm. Fruit firmness, total soluble solids (TSS), and titratable acidity (TA) were measured as described by Petrasch et al. (2022) from multiple fruit/replication sampled from two harvests/trial. EMMs and test statistics were estimated from the phenotypes of fruit harvested from two 24-plant plots/entry/environment.

[ii] t statistics for linear contrasts (EMM1 − EMM2) between 'UC Surfline' and check cultivar EMMs, where EMM1 is the EMM for UC Surfline, and EMM2 is the EMM for the check cultivar.

[iii] The probability of a greater t statistic by chance for tests of the null hypothesis of no difference between EMMs (H_0: EMM1 = EMM2).

[iv] Cumulative marketable fruit yield through 1 Mar harvests.

configurations, plastic mulches, planting densities, planting dates, irrigation, fertilization, and pesticide application decisions and schedules, and harvest schedules of our industry cooperators. The number of harvests ranged from 14 to 37 across farms (Figs. 2 and 3). The harvest was cut short in the 2021–22 growing season in Oxnard, CA, by weather (only 14 harvests). The number of harvests ranged from 26 to 37 in the other five field trials (Figs. 2 and 3). We recorded marketable fruit yield, count, and weight at each harvest (4695 observations for these traits were collected to support statistical analyses and selection decisions). We sampled fruit from early and peak season harvests to phenotype hybrids for firmness, total soluble solids (total soluble solids = Brix), and titratable acidity. Over three growing seasons, 2449 phenotypic observations were collected for these traits to support statistical analyses and selection decisions.

As described for 'UC Monarch' (Cole et al. 2025), 'UC Surfline', check cultivars, and 224 to 262 other hybrid individuals (full-sib progeny) were phenotyped for resistance to Fusarium wilt, Verticillium wilt, and Phytophthora crown rot over three growing seasons (Table 4). These individuals were screened by artificially inoculating bare-root plants (clones) with a single isolate of a single pathogen (four clones/individual/pathogen), which were planted in fumigated, disease-specific isolation blocks in November of each year. They were arranged in randomized complete block experiment designs and phenotyped for disease symptoms over several time points in the late spring and early summer (the statistics reported here were estimated from symptoms observed at the final time point each year). The artificial inoculation protocols, pathogen strains, and ordinal rating scales used in these studies have been previously described (Feldmann et al. 2024; Jiménez et al. 2023; Pincot et al. 2020, 2022). Over three growing seasons, 31,404 phenotypic observations were collected for these traits to support statistical analyses and selection decisions.

Table 2. Within-environment estimated marginal means (EMMs) for early season (before 1 Mar) cumulative marketable fruit yield for 'UC Surfline' and check cultivars grown on farms in coastal California over three growing seasons (2019–20 to 2021–22).[i]

Location	Season	Cultivar	EMM (kg/ha)	t[ii]	P value[iii]
Oxnard	2019–20	UC Surfline	7,679		
		Fronteras	6,816	0.29	0.80
		UCD Victor	3,315	1.44	0.29
Santa Maria	2019–20	UC Surfline	3,022		
		Fronteras	3,004	0.02	0.99
		UCD Victor	647	1.91	0.09
Oxnard	2020–21	UC Surfline	10,785		
		Fronteras	7,351	1.65	0.20
		UCD Victor	5,686	2.45	0.09
Santa Maria	2020–21	UC Surfline	10,208		
		Fronteras	5,123	6.28	0.01
		UCD Victor	1,162	11.17	0.002
Oxnard	2021–22	UC Surfline	8,122		
		Fronteras	9,406	−1.33	0.28
		UCD Victor	4,495	3.76	0.03
Santa Maria	2021–22	UC Surfline	6,845		
		Fronteras	6,462	0.62	0.58
		UCD Victor	3,242	5.86	0.01

[i]Linear contrasts between EMMs for 'UC Surfline' and check cultivars were estimated for each environment (location × year). Cumulative marketable fruit yields were estimated from fruit harvested on commercial schedules (once or twice weekly) from the start of harvest through 1 Mar. EMMs and test statistics were estimated from the phenotypes of fruit harvested from two 24-plant plots/entry.

[ii] t statistics for linear contrasts (EMM1 – EMM2) between the EMMs for 'UC Surfline' and check cultivars, where EMM1 is the EMM for 'UC Surfline', and EMM2 is the EMM for the check cultivar.

[iii] The probability of a greater t statistic by chance for tests of the null hypothesis of no difference between EMMs (H_0: EMM1 = EMM2).

Description

The short-day classification of 'UC Surfline' was confirmed by 6 years of field observation (2018–24) on multiple farms in California and Mexico. Using AX-184947290, a 50K Axiom single nucleotide polymorphism (SNP) array marker associated with the *PERPETUAL FLOWERING* (*PF*) locus (Hardigan et al. 2020), 'UC Surfline' and the check cultivars were predicted to be homozygous for a recessive *PF* allele (*pfpf*).

Figs. 2 and 3 display the harvest-to-harvest variation in marketable fruit yield across years and locations for 'UC Surfline' and the check cultivars 'Fronteras' and 'UCD Victor'. 'UC Surfline' was the most productive short-day cultivar in our tests (Table 1). The full-season cumulative yield of 'UC Surfline' was nearly 1 tonne/ha greater than 'Fronteras' (52,532 to 43,526 kg/ha = 9006 kg/ha; $P = 0.05$) and two-thirds of a tonne/ha greater than 'UC Victor' (52,532 to 45,814 kg/ha = 6538 kg/ha; $P = 0.15$) across years and locations (Table 1).

The early season (before 1 Mar) yields of 'UC Surfline' were outstanding (Tables 1–2). 'UC Surfline' produced 1175 kg/ha more fruit than 'Fronteras' ($P = 0.10$) and 4463 kg/ha ($P \leq 0.0001$) more fruit than 'UCD Victor'

Table 3. Within-environment estimated marginal means (EMMs) for full-season cumulative marketable fruit yield for 'UC Surfline' and check cultivars grown on farms in coastal California over three growing seasons (2019–20 to 2021–22).[i]

Location	Season	Cultivar	EMM (kg/ha)	t[ii]	P value[iii]
Oxnard	2019–20	UC Surfline	78,804		
		Fronteras	48,689	4.74	0.04
		UCD Victor	56,707	3.48	0.07
Santa Maria	2019–20	UC Surfline	57,292		
		Fronteras	57,873	−0.11	0.92
		UCD Victor	67,536	−1.49	0.18
Oxnard	2020–21	UC Surfline	71,788		
		Fronteras	51,837	1.91	0.15
		UCD Victor	66,902	0.47	0.67
Santa Maria	2020–21	UC Surfline	58,556		
		Fronteras	60,036	−0.24	0.82
		UCD Victor	58,598	−0.01	0.99
Oxnard	2021–22	UC Surfline	19,610		
		Fronteras	21,729	−3.43	0.04
		UCD Victor	15,479	6.70	0.007
Santa Maria	2021–22	UC Surfline	54,803		
		Fronteras	36,022	1.89	0.16
		UCD Victor	28,492	2.65	0.08

[i] Linear contrasts between EMMs for 'UC Surfline' and check cultivars were estimated for each environment. Cumulative marketable fruit yields were estimated from fruit harvested on commercial schedules (once or twice weekly) over the entire short-day growing season on each farm. EMMs and test statistics were estimated from the phenotypes of fruit harvested from two 24-plant plots/entry.
[ii] t statistics for linear contrasts (EMM1 – EMM2) between the EMMs for 'UC Surfline' and check cultivars, where EMM1 is the EMM for 'UC Surfline', and EMM2 is the EMM for the check cultivar.
[iii] The probability of a greater t statistic by chance for tests of the null hypothesis of no difference between EMMs (H_0: EMM1 = EMM2).

before 1 Mar (Table 1). The early season yields of 'UC Surfline' were greater than 'Fronteras' in 83% and greater than 'UC Victor' in 100% of our tests (Table 2).

The fruit of 'UC Surfline' are large and firm (Fig. 1; Table 1). 'UC Surfline' (339.1 g-force) fruit were 50% firmer than 'Fronteras' (225.9 g-force). The superior firmness of this cultivar is especially important in the later half of the short-day growing season when temperatures are higher and the softer fruit of 'Fronteras' are more prone to damage and deterioration. 'UC Surfline' and the check cultivars were genotyped with a 50K Axiom array SNP (AX-184242253) associated with the *POLYGALACTURONASE1* (*PG1*) locus and found to be homozygous for a *PG1* allele that increases fruit firmness (Jiménez et al. 2025). The fruit of 'UC Surfline' (29.5 g/fruit) were slightly smaller than 'Fronteras' (32.4 g/fruit) and identical to 'UC Monarch' (29.6 g/fruit) across locations and years (Table 1). The fruit quality traits of 'UC Surfline' were otherwise similar to the check cultivars (Table 1).

Fig. 1. The short-day strawberry cultivar UC Surfline, Apr 2023, Santa Maria, CA, USA. Photographs by Fred Greaves for UC Davis.

Table 4 displays disease resistance score means ($\bar{y}$) for 'UC Surfline' and five check cultivars estimated from ordinal disease symptom scores observed over 3 years, where 1 = highly resistant, 2 = moderately resistant, 3 = moderately susceptible, 4 = susceptible, and 5 = highly susceptible. The statistics shown in Table 4 were estimated from mixed model analyses of 230 to 268 individuals/year observed among four clones/individual/year. The most resistant cultivars in those tests were selected as checks for the statistical comparisons reported here.

'UC Surfline' was highly resistant to Fusarium wilt race 1 in our tests, as were the five check cultivars (Table 4). Using a 50K SNP (AX-184226354) associated with the *FW1* locus, 'UC Surfline' and the four check cultivars shown in Table 4 were predicted to be heterozygous for a dominant allele (*FW1*) that confers resistance to race 1 isolates of *Fusarium oxysporum* f. sp. *fragariae* (Pincot et al. 2018, 2022).

'UC Surfline' was highly resistant to Verticillium wilt ($\bar{y}$ = 1.62) and Phytophthora crown rot ($\bar{y}$ = 1.67) in our tests (Table 4). The resistance of 'UC Surfline' to these diseases was equivalent to the resistant check cultivar San Andreas (Feldmann et al. 2024; Jiménez et al. 2023; Pincot et al. 2020). Using a SNP marker (AX-184109190) associated with *RPc2*, a large-effect quantitative trait locus (Jiménez et al. 2023; Mangandi et al. 2017), 'UC Surfline' was predicted to be homozygous for a favorable *RPc2* allele that increases resistance to Phytophthora crown rot (Jiménez et al. 2023). The AX-184109190 SNP was genotyped using a 50K Axiom SNP array (Hardigan et al. 2020).

Table 4. Across-year estimated-marginal means (EMMs) for Fusarium wilt, Verticillium wilt, and Phytophthora crown rot scores[i] for 'UC Surfline' and check cultivars observed in 2019–20, 2020–21, and 2021–22 disease resistance screening trials at Armstrong Farm, Davis, CA, USA.

Disease[ii]	Cultivar	EMM	t[iii]	P value[iv]
Fusarium wilt	UC Surfline	1.02		
	Fronteras	1.09	−0.18	0.86
	UCD Victor	1.09	−0.17	0.87
	UC Monarch	1.22	−0.47	0.64
	UC Warrior	1.47	−0.98	0.33
	San Andreas	1.15	−0.27	0.79
Verticillium wilt	UC Surfline	1.62		
	Fronteras	1.71	−0.19	0.85
	UCD Victor	2.30	−1.58	0.12
	UC Monarch	1.79	−0.39	0.70
	UC Warrior	2.56	−2.23	0.03
	San Andreas	1.29	0.50	0.62
Phytophthora crown rot	UC Surfline	1.67		
	Fronteras	2.54	−1.68	0.10
	UCD Victor	2.19	−0.99	0.33
	UC Monarch	2.04	−0.66	0.51
	UC Warrior	2.03	−0.68	0.50
	San Andreas	1.83	−0.24	0.81

[i] The ordinal symptom rating scales were identical for each disease: 1 = highly resistant, 2 = moderately resistant, 3 = moderately susceptible, 4 = susceptible, and 5 = highly susceptible.
[ii] The fungal pathogens causing these diseases are *Fusarium oxysporum* f. sp. *fragariae* (Fusarium wilt), *Verticillium dahliae* (Verticillium wilt), and *Phytophthora cactorum* (Phytophthora crown rot).
[iii] t statistics for linear contrasts (EMM1 − EMM2) between 'UC Surfline' and check cultivar EMMs, where EMM1 is the EMM for 'UC Surfline', and EMM2 is the EMM for the check cultivar.
[iv] The probability of a greater t statistic by chance for tests of the null hypothesis of no difference between EMMs (H_0: EMM1 = EMM2).

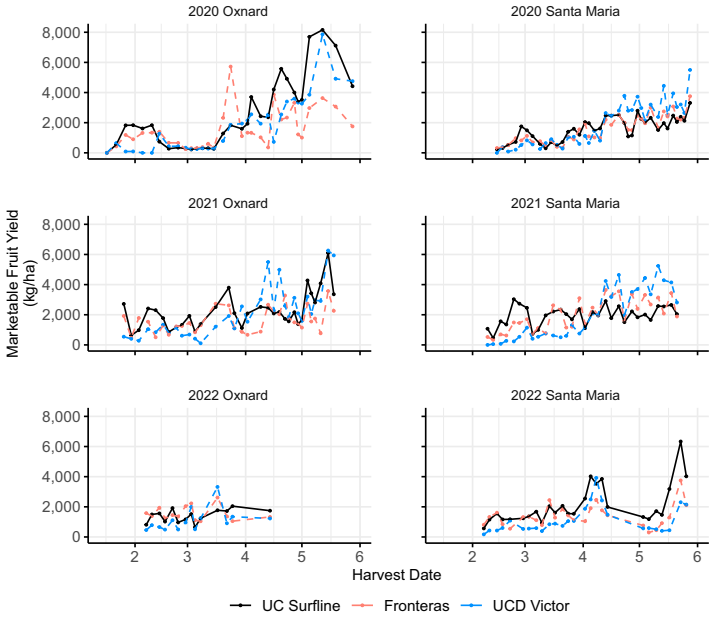

Fig. 2. Yields of marketable fruit for 'UC Surfline' (solid black lines) and three check cultivars (dashed colored lines) grown on farms in Oxnard and Santa Maria, CA, USA, over the 2019–20, 2020–21, and 2021–22 growing seasons. The points depict the phenotypic means (estimated marginal means) for every harvest (the number of harvests ranged from 14 to 37 across environments). Harvests were discontinued early on the Oxnard, CA farm in 2021–22. Harvests on the other farms ranged from 26 to 37 and spanned the typical short-day harvest seasons in California. UCD = University of California, Davis.

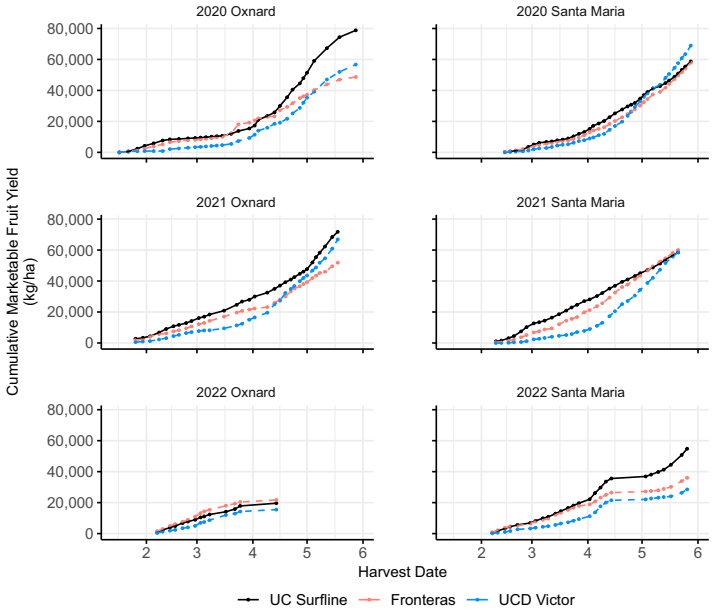

Fig. 3. Cumulative marketable fruit yields for 'UC Surfline' (solid black lines) and three check cultivars (dashed colored lines) grown on farms in Oxnard and Santa Maria, CA, USA, over the 2019–20, 2020–21, and 2021–22 growing seasons. The points depict the phenotypic means (estimated marginal means) for cumulative yield. The number of harvests ranged from 14 to 37 across environments). Harvests were discontinued early on the Oxnard, CA farm in 2021–22. Harvests on the other farms ranged from 26 to 37 and spanned the typical short-day harvest seasons in California. UCD = University of California, Davis.

Availability

The release of 'UC Surfline' was approved by the College of Agricultural and Environmental Sciences at the University of California, Davis in 2023. The US Plant Patent for 'UC Surfline' is pending. Plant Breeder's Rights are pending in territories outside the United States. Those interested in acquiring plants of 'UC Surfline' for commercial purposes should contact the Strawberry Licensing Program at Technology Transfer in the Office of Research at the University of California, Davis (https://research.ucdavis.edu/technology-transfer/plant-variety-licensing-program/strawberry-licensing-program/).

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