Almond Varieties and Selections

Evaluation of National and International Varieties or Selections Under Development

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Contents

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Introduction

The Almond Board of California began funding almond variety development research in the early 1970s and expanded that effort to include rootstock breeding in the late 1980s, investing an estimated $8 million to today. In the last twenty years, this research has delivered five new UC varieties (Padre, Sonora, Kester, Winters and Sweetheart), and supported testing of most commercial varieties and rootstocks for overall performance, resistance to pests, diseases and abiotic stresses, providing growers with information on options for different growing conditions.

Nurseries and private breeders have always played an important role in the introduction of new almond varieties and, in particular, accessing international rootstock for commercial release in California. To provide a mechanism to test the performance of new varieties across the diverse almond growing regions in the state, and under different soil conditions, in the 1970s the Almond Board began supporting long term and multilocational Regional Varietal Trials (RVTs), spanning from the following time periods: first trial: 1974-1981, second trial: 1993– 2006, third trial: 2014–present.

In November 2019, the ABC held its first ever “Crack-Out” event with the purpose engaging the entire industry in a more comprehensive evaluation of new almond varieties. This event brought together public and private breeders, growers and handlers, hullers/shellers, UC researchers and nurseries to sample more than 60 varieties of almonds. ABC staff and UC researchers collected nut samples from UC Davis and USDA breeding programs, private breeders, nurseries in California, and leading varieties from Australia, Spain and Israel.

Breeding is an art of balancing improvements while accepting some trade-offs. To define this balance, experts must consider the various segments of the almond industry, starting with the growers, moving to the hullers and shellers, handlers, food companies, and then, ultimately, the consumer.

Current California Almond Varieties

California produces about 30 varieties of almonds, with more than 98% of production represented by 13 major varieties. Nonpareil, which is more than 120 years old, is the dominate variety, accounting for about 40% percent of annual production. Nonpareil almond is a paper or soft-shell variety with an attractive kernel of a medium size, uniform shape, smooth surface and light (blond) colored skin. Nonpareil receives a premium price due to high market demand.

Many other varieties have been developed as pollinizers for Nonpareil. A few of them have kernel or shell characteristics similar to Nonpareil, and they may be marketed as “Nonpareil Type”. Examples of these varieties are Sonora, Independence and Supareil. These varieties also have a wide range of applications: in addition to snacking, they can be cut to various forms for ingredient applications.

The remaining pollinizer varieties, with a wide range of kernel shapes and sizes, have traditionally been marketed under two classifications according to their main kernel characteristics and uses: “Mission” and “California” types.

Mission type varieties have small, short and plump kernels with wrinkled surfaces and dark brown skin color. Butte, Padre, Butte/Padre (both varieties are often harvested together), Fritz, Mission, Ruby, and Marcona are marketed under this type for natural roasted, salted, and candy or chocolate applications. The major varieties in this group are Butte, Padre, Butte/Padre and Fritz. For years Butte, Padre, and Fritz have also been marketed under “California” type as they share the blanchable characteristic that defines that type. In addition, down the road the current Mission type may be renamed after the common Butte/Padre or “for Roast and Candy Use.” Alternately, production of Mission and Ruby are diminishing, while Marcona has only a small share of production.

The California type was established as input feedstock for manufacturing processes, i.e. blanching and slicing or slivering, about five decades ago. By definition, the varieties in this classification should be blanchable. Most major varieties produced in California except for Marcona can be marketed as California type. These include all Nonpareil type varieties; some “Mission” type varieties such as Butte, Padre, or Butte/Padre, and Fritz; and other varieties such as Carmel, Monterey, Wood Colony, Aldrich, Price, Winters, etc. California type varieties have a wide range of kernel shapes and sizes ranging from narrow medium, narrow long to narrow large, etc. with wrinkled surface and brown color. Due to high consumer demand for snack products, many varieties in this type are also used for roasting, salting or flavoring processes. Some of the varieties such as Carmel, Monterey, Wood Colony, etc., are also good for slicing or slivering process because of their large kernel sizes. In terms of industry use, Carmel production is decreasing, Wood Colony has irregular or bulging shapes with a high percentage of twins while Monterey has a relatively high level of doubles, considered a less desirable characteristic. Therefore, these varieties may be replaced with more desirable varieties in the future or may be reclassified based on different processing uses. Indeed, as new varieties enter production, the classification of these varieties is an area for additional industry dialog.

Evaluation of Variety Performance

The evaluation of new varieties and selections is subdivided in three parts, based on the source of the data presented:

I. **Results from the ongoing Regional Variety Trials (RVTs)**: These trials collect the most robust horticultural data available on newer almond varieties and selections being tested in California and are conducted by the UC with support from the Almond Board of California.
II. **Horticultural and quality data on non-RVT varieties and selections** from CA and around the world (Australia, Israel, and Spain). This data comes from promotional material, self-reported data from breeders and some published research.
III. **Data collected on all varieties during the Crack-Out event** held on November 13, 2019.

Part I: Preliminary Results from Ongoing Regional Variety Trials (RVTs)

Background

To provide a mechanism to test the performance of new varieties across the diverse almond growing regions in the state, and under different soil conditions, in the 1970s the Almond Board began supporting long term and multilocational Regional Varietal Trials (RVTs). All but one of the top 15 current California almond varieties, ranked by their total market share according to 2019/20 crop receipts[1], have been included in past or current RVTs funded by ABC (Table I-1).

Table I-1. Top 15 California Almond and their evaluation in RVTs

2019/20 Receipts by Variety	Kernels (lbs)	Origin	Self-fertile	RVT#1 1974-1981	RVT#2 1993-2006	RV#3 2014 - present
Nonpareil (NP)	1,045,977,062	A.T. Hatch - Grower, Suisan, Solano County, 1879		x	x	x
Monterey	455,921,902	Chance seedling, Merced 1962, NP x Mission, US patent 3483, 1974		x	x	
Butte/Padre	194,532,090	See below				
Independence	156,723,441	Private breeder, Zaiger Genetics 2008, available exclusively through Dave Wilson Nurseries	x			
Carmel	119,283,990	Chance seedling, Merced, 1966, NP x Mission, US patent 2641		x	x	

[1] View past ABC-issued monthly Position Reports for more information on crop receipts: https://www.almonds.com/tools-and-resources/crop-reports/position-reports.

2019/20 Receipts By variety	Kernels (lbs)	Origin	Self-fertile	RVT#1 1974-1981	RVT#2 1993-2006	RV#3 2014 - present
Fritz	109,654,952	Chance seedling, Manteca 1969, Mission x Drake, US patent 3005, assigned to Burchell		x	x	
Wood Colony	99,133,138	Chance seedling, Modesto, 1985 US patent 5583, assigned - Burchell			x	x
Aldrich	89,363,689	Chance seedling, Hughson 1973, US patent 5320			x	x
Butte	77,125,048	Private breeder, F.W. Anderson, Merced, 1963, Mission x NP assigned to Fowler		x	x	
Mixed	58,545,611					
Sonora	29,477,605	UC Davis - Kester, 1983, no patent, NP x Eureka cross 1946		x	x	
Padre	23,141,647	UC Davis – Kester 1983, no patent, Mission x Swanson 1946			x	
Price	19,211, 083	Chance seedling, Durham, 1953, NP x Mission, US patent 2350 1964		x	x	
Winters	11,668,704	UC Davis NP x Peerless & others, US Patent 13,286 P34 2006				X
Supareil	10, 317,522	Chance seedling, B. Crocker, Chico US patent 21,934 2011, available exclusively through Burchell				x

RVTs are designed to evaluate new varieties or selections in a semi-commercial (20 to 40 trees per variety) manner and to compare them to standard varieties such as Nonpareil, Mission and currently accepted pollinizer varieties. Initial RVTs were established between 1974 and 1981 in Kem, Colusa, Butte, San Joaquin and Fresno counties. Trees in these trials were planted over several years and made up of different ages and variety combinations. Thus, the data from these early trials was not directly comparable.

In 1993, a more uniform RVT was initiated. This second RVT was conducted in Butte, San Joaquin and Kem Counties. To be comparable, these three new trials were all planted in the same year and with essentially the same variety composition. Thus, any differences in varietal performance among various regions should have been evident. Collection of yield data from the second RVT was discontinued on most varieties in 2006. The results of these trails were summarized and are available in a 2006 Annual Research Report available in the UC Fruit and Nut Center: http://fruitsandnuts.ucdavis.edu/dsadditions/Regional_Almond_Variety_Trials/.

In 2004, a limited variety trial was planted near McFarland (Kern County) to evaluate the performance of eight clones of Nonpareil and eight pollinizer varieties. Production data on this trial was collected from 2006 to 2015. For summaries of the results from this trial see the 2012, 2014 and 2015 ABC Annual Research Reports titled “Field Evaluation of Almond Varieties” by Bruce Lampinen et al. at https://rd.almondboard.com/Pages/default.aspx.

A third, more uniform RVT was initiated with trees planted in 2014 in Butte, Stanislaus and Madera counties. 30 varieties and breeder selections were planted at each site (Table I-2) and a few additional genotypes were planted at individual sites. The source of the current RVT genotypes includes collections from private nurseries as well as USDA and UC Davis breeding programs. The thirty varieties and selections currently in the RVTs are a combination of recently released varieties and promising advanced selections, and 14 are self-compatible, with most of the new selections coming from the ABC-supported breeding program at UC Davis. The advanced selections combine California quality and adaptability with novel traits for self-fruitfulness and disease and pest resistance. The advance selections also demonstrate a range of tree sizes, architectures and bearing habits required for developing more efficient orchard systems in the future. A list of the materials in the current RVT are as follows:

Table I-2. Varieties and selections planted at the 2014 RVT. Trees at the Butte, Stanislaus and Madera sites were planted on Krymsk 86, Nemaguard, and Hansen 536 rootstocks, respectively (exceptions are noted at bottom of table). Twelve selections are self-compatible, two selections are partially self-compatible, and 16 have pollen incompatibility.

Variety	Source	Provided budwood	Self-compatible?
Eddie	Bright's	Bright's	No
Capitola	Burchell	Burchell	No
Supareil	Burchell	Burchell	No
Self-fru P16.013	Burchell	Burchell	Yes
Self-fru P13.019	Burchell	Burchell	Yes
Booth	Burchell	Burchell	No
Sterling	Burchell	Burchell	No
Bennett	Duarte	Duarte	No
Nonpareil	Fowler	Fowler	No
Durango	Fowler	Fowler	No
Jenette	Fowler	Fowler	No
Aldrich	Fowler	Fowler	No
Winters	UCD	Fowler	Partial
Sweetheart	UCD	Fowler	Partial
(2-19E) Kester	UCD	Gradziel	No
(2-19E) Kester/Hansen	UCD	Gradziel	No
UCD 3-40	UCD	Gradziel	No
UCD 18-20	UCD	Gradziel	No
UCD 1-16	UCD	Gradziel	No
UCD 8-160	UCD	Gradziel	Yes
UCD 8-27	UCD	Gradziel	Yes
UCD 1-271	UCD	Gradziel	Yes
UCD 1-232	UCD	Gradziel	Yes
UCD 7-159	UCD	Gradziel	Yes
UCD 8-201	UCD	Gradziel	Yes
Y121-42-99	USDA	Ledbetter	Yes
Y117-86-03	USDA	Ledbetter	Yes
Y116-161-99	USDA	Ledbetter	Yes
Y117-91-03	USDA	Ledbetter	Yes
Folsom	Wilson	Wilson	No
Wood Colony*	Sierra Gold	Sierra Gold	No

* Wood Colony only planted in Butte County at California State University, Chico

Among the data collected on each variety and selection in the third RVT are:

- timings of bloom, hull split and harvest,

- yield and canopy light interception to help interpret and normalize yield data to account for differences in tree size/canopy volumes among genotypes and sites,
- kernel characteristics, and
- observations on disease susceptibility, ease of harvest and other horticultural characteristics.

Further data, methods, and year-specific results can be found on the Almond Board's Research Database: https://rd.almondboard.com/Pages/default.aspx

Results

For the purposes of this report only preliminary summary data from the most recent four years (2016, 2017, 2018, 2019) are presented. The first significant yields in these trials were obtained in 2016 and full yields were not obtained until 2018 or 2019. The site with the highest tree density (Madera) obtained higher early yields than the other two sites. While the yield data averaged across all sites presented here probably do not reflect potential mature tree/orchard yields they do provide information about the general differences in performance of the various varieties and selections in the trials. The data on yields divided by canopy light interception probably provide a better idea of the general yield potential of the varieties/selections, especially in these early years of the trials because much of the differences in yields among genotypes and sites are due to rates of tree growth and canopy volume. Thus, it is important to point out that trees were planted at a spacing of 18' x 22' at the Butte site (110 trees/acre) on Krymsk 86 rootstock, 16' x 21' at the Stanislaus site (130 trees/acre) on Nemaguard rootstock, and 12' x 21' at the Madera site (173 trees/acre) on Hansen 536 rootstock.

Bloom date

With the exception of a few genotypes, the majority of cultivars in the RVTs bloomed within a ten-day period at each of the sites. Furthermore, there was only a 1-3 day difference in average bloom date of each variety among sites. The earliest blooming selection was UCD 3-40, having a full bloom date within the second week in February (Table I-3). About 20% of varieties/selections had full bloom in the third week in February, and 68% (inclusive of Nonpareil) had full bloom extending into the fourth week of February. Only Kester on Hansen rootstock had an average bloom date of March 1.

Table I-3. Average full bloom calculated from adjusted means for three years (2017, 2018, 2019) for each location (Butte, Madera, Stanislaus) in RVT.

Variety	Full Bloom Date		
	Butte (Avg)	Madera (Avg)	Stanislaus (Avg)
Aldrich	02-20	02-21	02-23
Bennett	02-21	02-22	02-24
Booth	02-21	02-22	02-23
Capitola	02-19	02-20	02-21
Durango	02-21	02-22	02-23
Eddie	02-21	02-21	02-23
Folsom	02-26	02-27	02-28
Jenette	02-22	02-23	02-24
Kester	02-26		02-28
Kester/Hansen	02-28	03-01	03-02
Lonestar [1]	02-16		02-19
Nonpareil	02-21	02-22	02-23
Self-fru P13.019	02-24	02-25	02-27
Self-fru P16.013	02-25	02-25	02-27
Shasta[2]			02-24
Sterling	02-21	02-22	02-23
Supareil	02-20	02-21	02-23
Sweetheart	02-21	02-22	02-24
UCD 1-16	02-20	02-21	02-23
UCD 1-232	02-23	02-24	02-25
UCD 1-271	02-22	02-23	02-25
UCD 18-20	02-23	02-24	02-25
UCD 3-40	02-08	02-09	02-11
UCD 7-159	02-20	02-21	02-22
UCD 8-160	02-21	02-22	02-24
UCD 8-201	02-25	02-26	02-27
UCD 8-27	02-19	02-20	02-22
Winters	02-21	02-21	02-23
Wood Colony	02-22	02-23	
Y116-161-99	02-21	02-22	02-23
Y117-86-03	02-26	02-27	02-28
Y117-91-03	02-24	02-25	02-26
Y121-42-99	02-25	02-26	02-28

[1]Lone Star only in Butte and Stanislaus 2017, 2018, [2]Shasta only in Stanislaus 2019

Nut quality

Crack-out percentages were highest for Kester/Hansen, Eddie, UCD 7-159, Y117-91-03, Folsom, Bennett, **Nonpareil and** Jenette varieties (Figure I-1).

Forty four percent of the genotypes had a crack-out percentage greater than 60 percent, with 42 percent of the selections/varieties having more than 75 percent sealed nutshells. The percent of sealed shells, as measured with from a fifty-nut sample, was highest among Kester, Self-fruitful P13.019, Self-fruitful P16.013, Sweetheart, Capitola, Y121-42-99 and, Y117-86-03 (Figure I-2).

The quality defect of percent doubles varied greatly among genotypes. There were a number with doubles less than 3% including Eddie, Sweetheart, UCD 7-159, Sterling, Supareil, **Nonpareil**, Y116-161-99, and UCD 1-271. Eight genotypes produced 10% or greater double kernels: Booth, Self-fru P16.013, Wood Colony, UCD 8-201, UCD 18-20, UCD 8-27, Y 121-42-99 and UCD 1-16 (Figure I-3). The percent of shriveled kernels was found to be below 3% in several varieties: Winters, Y121-42-99, Durango, UCD 1-16, Sterling, and Kester (Figure I-4).

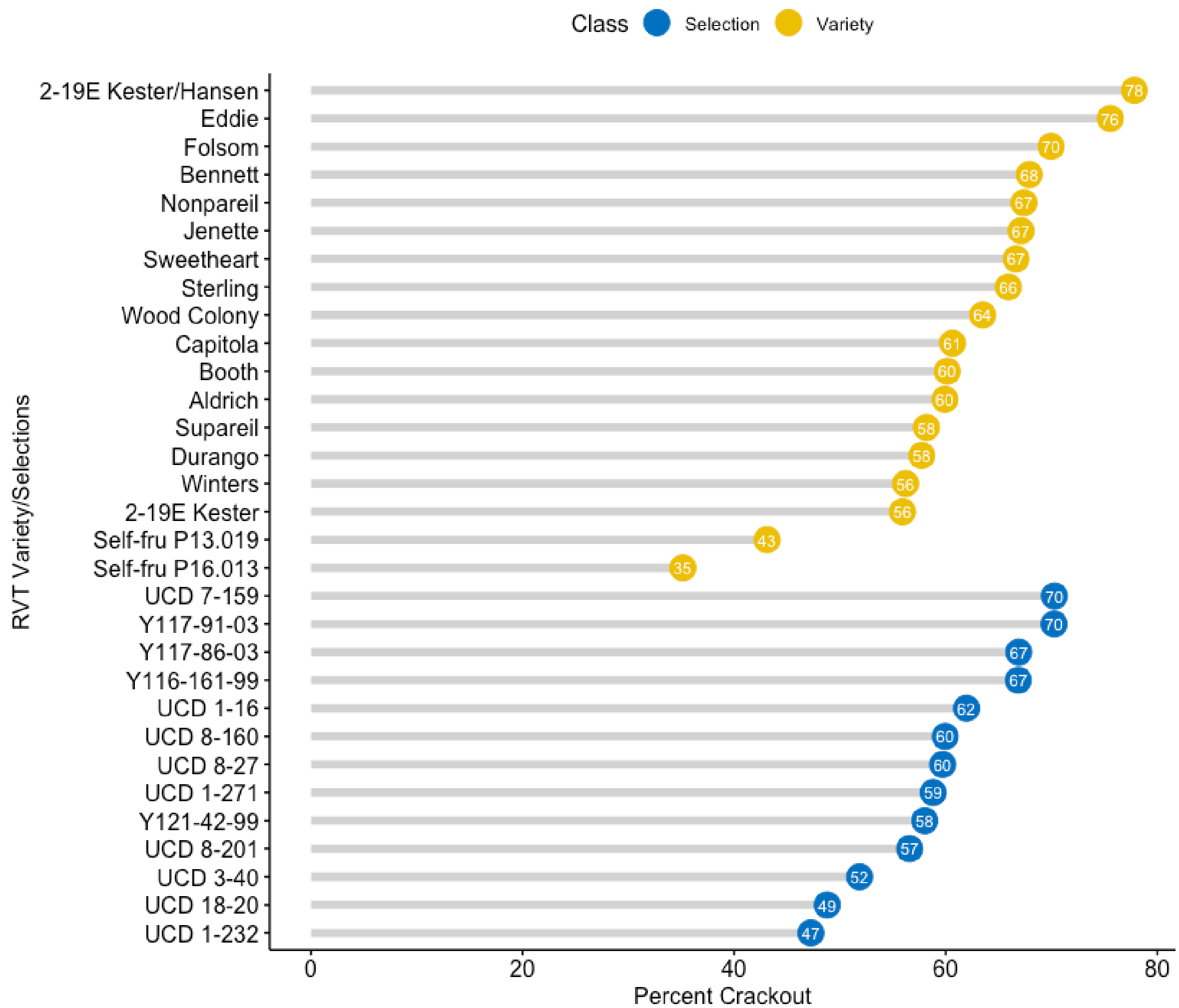


Figure I-1. Crack-out percent calculated for each selection or variety in the RVT. Adjusted means were calculated for the four years of data collection (2016, 2017, 2018, 2019) over three locations (Stanislaus, Madera, Butte).

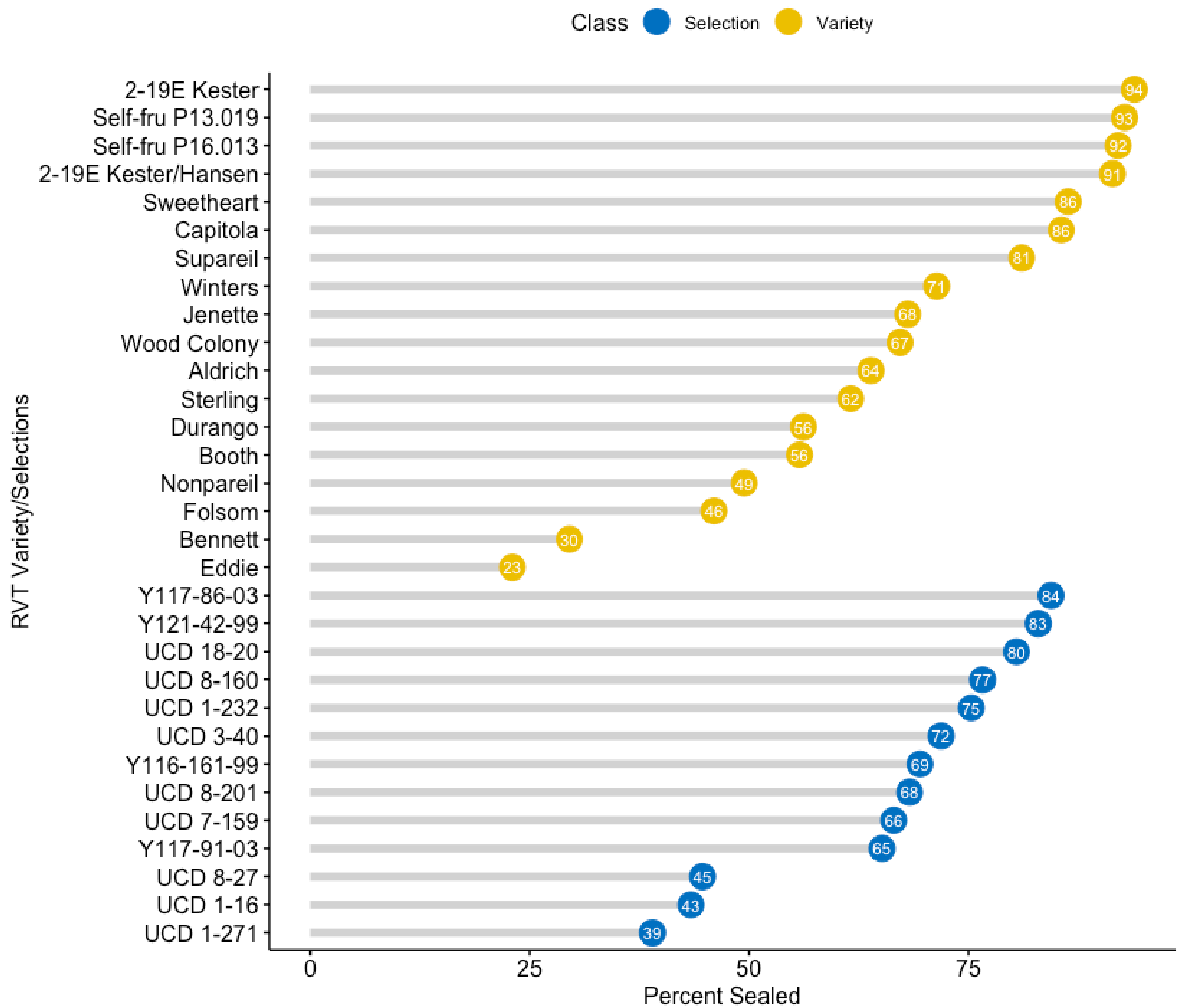


Figure I-2. Percent sealed calculated for each selection or variety in the RVT. Adjusted means were calculated for the four years of data collection (2016, 2017, 2018, 2019) over three locations (Stanislaus, Madera, Butte).

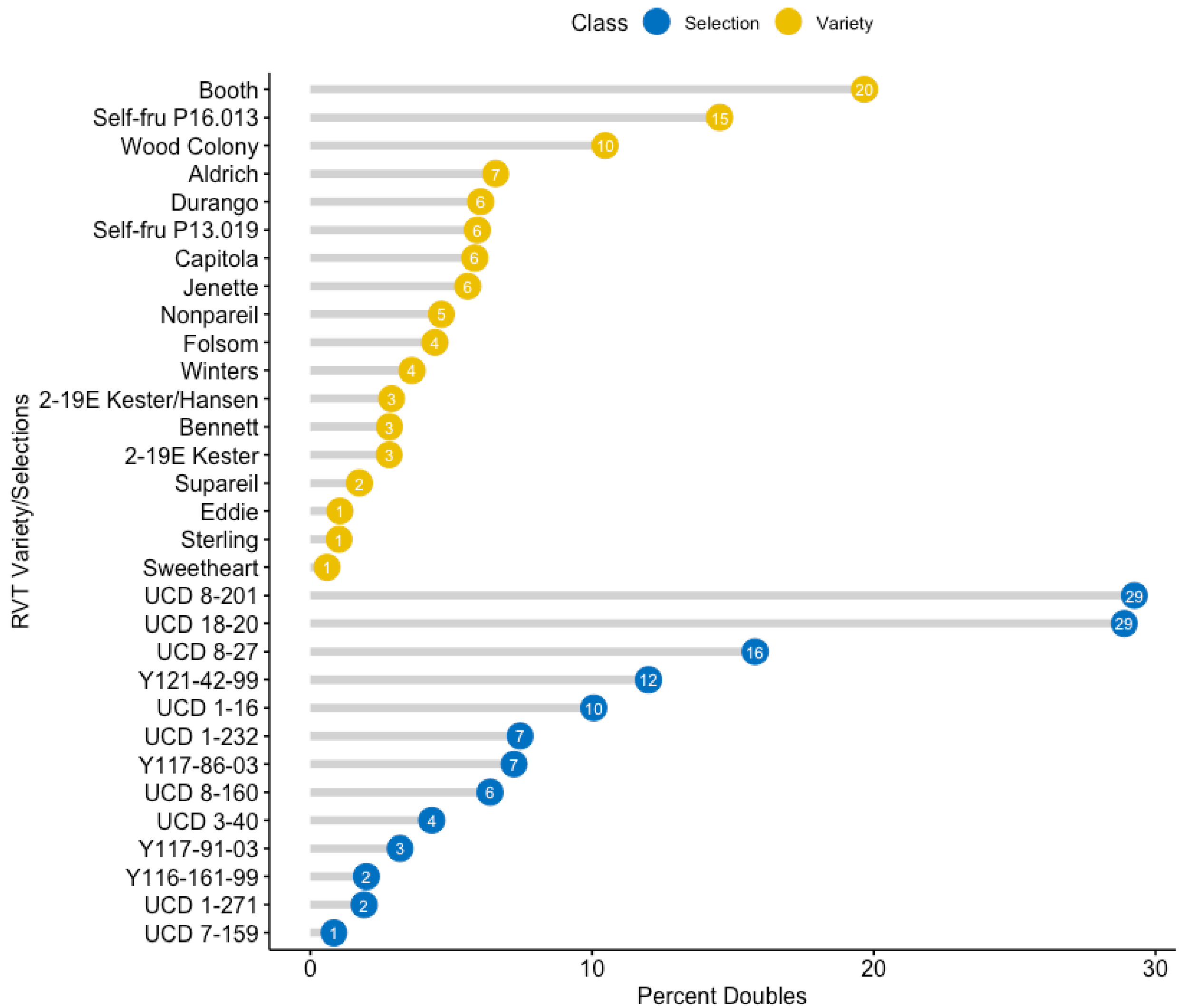


Figure I-3. Quality defect percent doubles calculated for each selection or variety in the RVT. Adjusted means were calculated for the four years of data collection (2016, 2017, 2018, 2019) over three locations (Stanislaus, Madera, Butte).

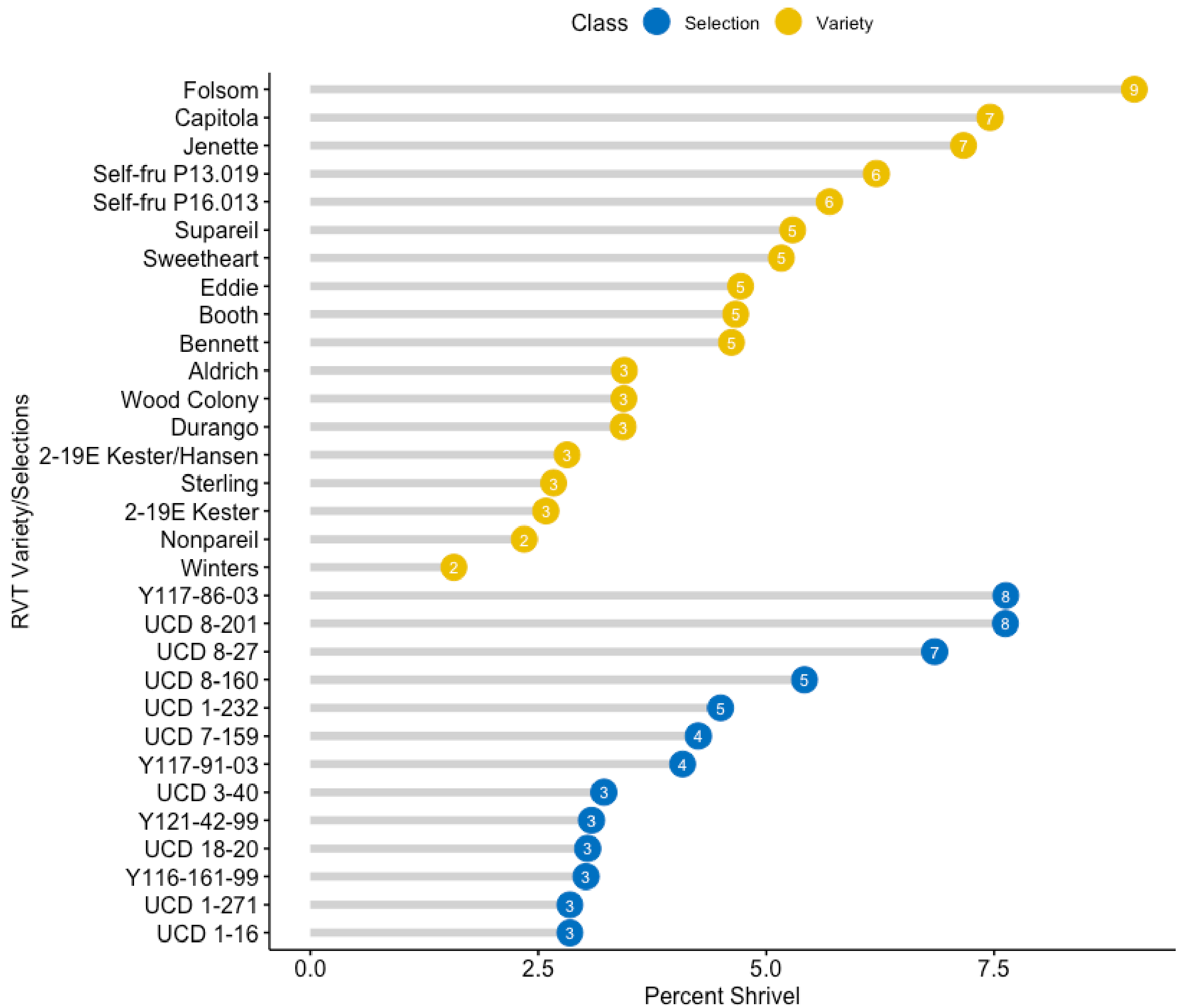


Figure I-4. Quality defect percent shrivel calculated for each selection or variety in the RVT. Adjusted means were calculated for the four years of data collection (2016, 2017, 2018, 2019) over three locations (Stanislaus, Madera, Butte).

Kernel yield

The tables below summarize the varieties' yield performance of the varieties (**Tables I-4A - Table I-4C).** Quality and defect characteristics are summarized in **Table I-5**.

Tables I-4A. Yield characteristics for 31 variety/selections in RVTs. Data displayed over four years (2016, 2017, 2018, 2019) from **Butte trial location** and ranked by the 2018 and 2019 average yield per photosynthetic active radiation (PAR) intercepted.

Variety or Selection	2016 Yield kernel (lbs./ac)	2017 Yield kernel (lbs./ac)	2018 Yield kernel (lbs./ac)	2019 Yield kernel (lbs./ac)	Cum. Yield (lbs./ac)	2018 Canopy PAR (%)	2018 Yield per PAR intercepted	2019 Canopy PAR (%)	2019 Yield per PAR intercepted	2018-19 Avg Yield per PAR intercepted
Jenette	271	1524	2555	2505	6855	50.1	51.4	57.5	43.6	47.5
Aldrich	316	1031	3265	2024	6636	56.0	58.5	65.0	31.1	44.8
UCD 8-160	670	1708	1941	1808	6127	40.8	47.9	48.5	37.4	42.7
Y116-161-99	529	823	2669	1811	5832	51.7	51.7	55.6	32.6	42.2
Nonpareil	447	2085	2846	2999	8377	68.4	41.6	74.2	40.4	41.0
UCD 18-20	717	1933	2648	2368	7666	63.3	42.0	70.7	33.5	37.7
Booth	796	1982	2344	2613	7735	63.6	36.8	71.3	36.5	36.6
Bennett	291	902	2278	1958	5429	51.7	43.9	67.1	29.2	36.6
UCD 8-201	517	1405	2168	1842	5932	52.7	40.8	61.5	30.4	35.6
Durango	390	1271	2440	2086	6187	60.5	40.5	68.7	30.3	35.4
Wood Colony	419	1382	1548	1989	5338	48.1	31.8	53.1	37.3	34.6
Y117-91-03	481	1500	2779	1878	6638	65.4	42.6	73.6	25.5	34.0
Y117-86-03	460	932	2264	1846	5502	58.2	38.7	66.6	27.7	33.2
Eddie	447	1090	2028	1748	5313	57.3	34.3	62.9	27.2	30.8
UCD 1-16	556	964	1854	1947	5321	58.2	31.8	66.5	29.7	30.8
Self-fru P13.019	764	1117	1160	1803	4844	60.0	29.0	63.8	28.5	28.8
Kester	649	1114	1892	2006	5661	64.3	29.3	72.0	27.8	28.6
UCD 8-27	507	1105	1677	1790	5079	57.3	29.3	66.9	26.8	28.0
UCD 7-159	211	1019	1121	2114	4465	56.9	19.8	60.6	34.9	27.3
Kester/Hansen	609	1060	1763	1785	5217	62.6	27.5	65.0	27.0	27.3
Sterling	336	922	1645	1828	4731	61.9	26.4	67.6	27.1	26.7
Winters	469	2040	657	2283	5449	60.2	11.0	70.9	42.3	26.7
Folsom	523	1583	1605	2016	5727	65.7	24.4	72.9	27.7	26.0
UCD 3-40	347	735	570	2701	4353	58.6	8.0	72.2	41.1	24.6
Capitola	455	1500	1315	2461	5731	74.0	17.8	78.8	31.1	24.5
UCD 1-232	712	1869	881	1819	5281	53.1	16.6	57.8	31.4	24.0
Sweetheart	311	526	1486	1801	4124	64.7	22.8	73.8	24.4	23.6
Self-fru P16.013	577	712	1552	1049	3890	42.0	26.0	53.6	19.9	23.0
UCD 1-271	159	405	1037	870	2471	44.0	23.6	53.8	16.2	19.9
Supareil	308	773	676	2071	3828	67.6	10.0	78.6	26.3	18.2
Y121-42-99		1597			1597					

Tables I-4B. Yield characteristics for 31 variety/selections in RVTs. Data displayed over four years (2016, 2017, 2018, 2019) for **Stanislaus trial location** and ranked by the 2018 and 2019 average yield per photosynthetic active radiation (PAR) intercepted.

Variety or Selection	2016 Yield kernel (lbs./ac)	2017 Yield kernel (lbs./ac)	2018 Yield kernel (lbs./ac)	2019 Yield kernel (lbs./ac)	Cum. Yield (lbs./ac)	2018 Canopy PAR (%)	2018 Yield per PAR intercepted	2019 Canopy PAR (%)	2019 Yield per PAR intercepted	2018-19 Avg Yield per PAR intercepted
UCD 8-160	224	2058	2006	1992	6280	42.8	46.6	40.4	49.4	48.0
UCD 18-20	262	1971	2368	2121	6722	50.8	46.8	51.6	41.6	44.2
UCD 7-159	40	1417	2246	1780	5483	46.5	48.0	44.4	40.1	44.0
Y116-161-99	325	1437	2107	1739	5608	44.3	47.9	42.8	39.9	43.9
Aldrich	162	1675	2331	1480	5648	45.8	51.0	45.7	32.5	41.7
Nonpareil	175	1408	2043	1377	5003	41.4	48.9	44.7	34.0	41.4
Kester/Hansen	345	1600	2614	2630	7189	63.1	42.2	65.6	40.6	41.4
Y121-42-99	373	1411	2336	1356	5476	48.5	48.8	43.4	30.9	39.8
Y117-86-03	213	1536	2033	1465	5247	46.1	44.3	43.4	33.9	39.1
Winters	195	1544	2136	1341	5216	51.6	41.4	41.9	36.4	38.9
Bennett	334	1473	2321	1442	5570	48.1	47.5	49.5	28.7	38.1
UCD 8-201	123	1569	1549	1660	4901	45.0	34.8	42.6	39.0	36.9
Durango	159	1467	1825	1495	4946	47.9	38.1	47.4	31.6	34.9
Sterling	54	1465	2003	1447	4969	51.4	40.4	51.5	29.2	34.8
Kester	321	1648	1818	1618	5405	49.7	36.9	50.0	32.4	34.7
UCD 1-232	225	1404	1498	1646	4773	50.0	30.2	46.3	36.2	33.2
Booth	128	1550	2226	1498	5402	56.0	39.8	56.8	26.4	33.1
Capitola	123	1365	2262	1284	5034	53.1	42.5	54.7	23.4	33.0
Y117-91-03	177	1918	2172	1763	6030	59.7	36.4	59.8	29.4	32.9
UCD 1-271	86	1234	1613	1630	4563	50.3	32.0	49.8	32.8	32.4
Self-fru P13.019	460	1783	1977	1558	5778	55.0	35.0	53.3	29.7	32.4
Jenette	120	1396	1458	1322	4296	47.6	30.8	45.6	29.1	29.9
UCD 1-16	357	1223	1353	1295	4228	43.4	30.4	44.9	29.1	29.8
Folsom	281	1241	1316	1573	4411	54.6	24.1	49.5	33.7	28.9
Self-fru P16.013	149	1252	1677	810	3888	45.0	32.0	40.7	23.4	27.7
UCD 8-27	178	907	1601	1062	3748	49.3	32.6	51.3	20.6	26.6
Sweetheart	178	936	1612	1554	4280	58.2	27.7	61.8	25.2	26.4
Eddie	309	1285	1827	964	4385	52.4	35.0	55.4	17.5	26.3
Supareil	53	1042	1130	1968	4193	56.7	19.7	60.2	32.6	26.1
UCD 3-40	133	1016	1365	1341	3855	54.6	25.2	54.5	24.9	25.0

Tables I-4C. Yield characteristics for 31 variety/selections in RVTs. Data displayed over four years (2016, 2017, 2018, 2019) for **Madera trial location** and ranked by the 2018 and 2019 average yield per photosynthetic active radiation (PAR) intercepted.

Variety or Selection	2016 Yield kernel (lbs./ac)	2017 Yield kernel (lbs./ac)	2018 Yield kernel (lbs./ac)	2019 Yield kernel (lbs./ac)	Cum. Yield (lbs./ac)	2018 Canopy PAR (%)	2018 Yield per PAR intercepted	2019 Canopy PAR (%)	2019 Yield per PAR intercepted	2018-19 Avg Yield per PAR intercepted
Y116-161-99	1804	2604	3056	2716	10180	67.0	47.5	70.2	40.5	44.0
UCD 18-20	1680	2226	3227	2434	9567	63.5	50.9	68.3	36.5	43.7
Y117-86-03	1995	1807	3483	1896	9181	63.6	54.9	65.1	29.5	42.2
UCD 8-160	964	1596	2362	2280	7202	56.7	41.3	59.7	39.2	40.3
Y117-91-03	1427	2042	2872	2124	8465	66.3	43.1	67.7	31.7	37.4
Jenette	1644	1783	2481	2200	8108	63.1	39.8	67.0	33.4	36.6
UCD 8-201	1310	1671	2644	1770	7395	61.0	42.4	64.0	29.6	36.0
Kester	1783	1840	2407	2467	8497	71.6	33.9	78.1	31.6	32.7
Sweetheart	1429	1210	1997	2833	7469	74.2	27.3	78.5	37.0	32.2
Y121-42-99	1533	1758	2675	1981	7947	70.7	37.9	82.9	23.9	30.9
UCD 1-16	1469	1647	1275	2741	7132	61.5	20.6	68.8	40.7	30.7
Nonpareil	1360	2341	2327	2429	8457	69.9	33.2	87.0	28.1	30.6
Wood Colony	49	675	1527	2088	4339	58.7	26.9	66.6	32.6	29.7
Self-fru P13.019	1606	1417	1808	1802	6633	66.0	29.0	72.2	29.37	29.2
Bennett	1770	1977	2800	1021	7568	65.5	42.6	72.0	14.4	28.5
Winters	1369	2066	340	3521	7296	65.4	5.0	71.2	50.2	27.6
UCD 7-159	775	1465	1490	2306	6036	68.2	21.8	72.3	32.6	27.2
UCD 8-27	1145	1022	2059	1846	6072	68.5	29.6	74.2	24.7	27.1
Eddie	1262	2167	2156	1824	7409	72.7	29.4	83.8	22.1	25.7
Self-fru P16.013	1911	1931	1645	1183	6670	60.0	35.0	77.9	15.29	25.1
Aldrich	1724	1413	1907	1819	6863	71.9	26.4	78.6	22.9	24.6
Sterling	1112	1889	1479	2285	6765	73.9	20.6	87.6	26.1	23.3
Capitola	1781	2190	1124	2925	8020	83.3	13.5	89.2	32.9	23.2
Folsom	1052	1818	1437	2668	6975	82.3	17.2	91.2	29.1	23.1
UCD 1-232	954	1490	1051	1890	5385	71.3	14.7	68.6	27.5	21.1
Booth	1857	2247	1137	2536	7777	80.2	14.2	89.1	27.9	21.0
Durango	1415	1827	1570	1406	6218	69.0	22.7	76.7	18.6	20.7
Supareil	1010	1791	800	2468	6069	81.2	9.9	88.1	28.1	19.0
UCD 1-271	409	1137	1268	462	3276	74.2	17.2	80.1	5.7	11.5
UCD 3-40	577	708	236	507	2028	74.2	3.2	76.9	6.8	5.0

Tables I-5. Quality and defects characteristics for 31 variety/selections in RVTs. Data displayed as means over four years (2016, 2017, 2018, 2019) across three locations (Butte, Stanislaus and Madera). Data taken by Gradziel and Lampinen et al. 50 almonds per tree. Twin = two kernels within the same nut. NOW = Navel Orangeworm. Blank = blank kernels.

Variety/Selection	Inshell wt. (g)	Kernel wt. (g)	Crack-out (%)	Sealed (%)	Blank (%)	Broken/Chip (%)	Callus (%)	Crease (%)	Discoloration (%)	Doubles (%)	Gum (%)	Mold (%)	NOW (%)	Shrivel (%)	Twin (%)
Aldrich	1.73	1.02	59.92	63.88	3.22	2.37	0.79	7.06	6.62	6.56	0.66	2.34	1.70	3.44	2.86
Bennett	1.70	1.15	67.90	29.51	1.92	1.13	0.20	7.78	15.83	2.80	2.30	13.73	3.73	4.61	2.46
Booth	2.16	1.29	60.15	55.75	7.62	1.79	0.79	11.29	11.91	19.66	0.45	8.29	2.37	4.66	4.58
Capitola	1.96	1.17	60.64	85.58	3.16	0.91	0.20	11.58	20.62	5.83	0.25	12.79	2.08	7.45	2.24
Durango	2.44	1.21	57.71	56.19	1.41	1.87	0.29	8.80	9.04	6.04	2.09	3.83	2.63	3.43	2.97
Eddie	2.02	1.52	75.54	23.00	1.46	0.59	1.74	7.22	26.03	1.04	1.11	21.53	2.96	4.71	3.94
Folsom	1.65	1.13	69.95	45.99	3.58	1.83	1.25	11.29	13.79	4.41	2.83	9.66	1.66	9.04	6.50
Jenette	1.73	1.16	67.12	68.08	3.91	1.20	0.58	15.79	10.75	5.58	0.58	6.12	1.54	7.16	10.25
Kester	1.85	1.02	55.91	93.91	1.08	1.20	0.12	7.66	11.58	2.79	0.08	12.79	0.25	2.58	4.87
Kester/ Hansen	1.85	1.43	77.82	91.37	1.14	1.29	0.13	7.40	14.62	2.86	0.15	11.68	0.93	2.80	3.04
Nonpareil	1.81	1.21	67.38	49.41	2.20	0.96	0.17	13.04	16.99	4.63	0.09	17.59	1.51	2.33	6.93
Self-fru P13.019	3.24	1.18	43.11	92.79	1.50	13.88	0.21	4.40	15.18	5.92	0.11	10.66	1.23	6.20	0.76
Self-fru P16.013	4.05	1.38	35.15	92.04	4.73	16.80	2.42	4.22	11.45	14.52	1.78	4.57	0.92	5.69	4.91
Sterling	1.62	1.06	65.92	61.58	1.25	0.91	0.23	22.56	15.73	1.01	0.36	8.72	1.41	2.66	1.41
Supareil	2.68	1.54	58.18	81.08	2.02	1.69	0.47	5.94	21.29	1.73	0.29	8.51	1.83	5.29	1.69
Sweetheart	1.56	1.03	66.64	86.36	1.87	2.08	0.04	8.16	18.70	0.58	0.03	8.71	1.12	5.16	11.16
UCD 1-16	1.82	1.13	61.96	43.37	3.37	1.80	1.08	7.47	11.06	10.05	0.45	9.47	3.25	2.84	1.19
UCD 1-232	2.67	1.22	47.24	75.31	3.97	3.41	2.31	10.63	29.36	7.44	1.33	6.88	0.70	4.50	4.68
UCD 1-271	2.30	1.35	58.80	38.97	1.95	3.05	0.20	8.83	43.37	1.90	1.48	19.95	2.94	2.84	1.29
UCD 18-20	2.80	1.31	48.77	80.47	4.43	6.56	1.52	6.29	8.02	28.88	0.31	2.26	1.55	3.04	0.79
UCD 3-40	3.17	1.60	51.85	71.87	1.75	4.31	1.98	7.60	31.98	4.30	5.41	12.35	3.31	3.21	16.86
UCD 7-159	2.29	1.61	70.28	66.47	1.91	0.70	1.94	17.76	17.95	0.83	0.21	12.85	3.33	4.25	4.90
UCD 8-160	2.51	1.49	59.94	76.60	1.38	1.24	1.24	23.84	17.18	6.37	1.52	8.27	1.17	5.42	5.66
UCD 8-201	1.94	1.08	56.57	68.29	2.66	2.12	2.87	10.83	16.25	29.25	0.20	10.00	2.87	7.62	8.83
UCD 8-27	1.83	1.08	59.70	44.69	3.54	3.14	1.02	6.60	15.38	15.78	0.37	9.84	4.94	6.85	12.65
Winters	1.97	1.11	56.20	71.38	0.60	3.38	0.34	6.99	19.95	3.60	0.93	5.80	2.10	1.57	1.72
Wood Colony	1.98	1.24	63.51	67.24	2.60	2.27	0.39	16.06	11.56	10.47	0.10	5.94	1.23	3.43	2.49
Y116-161-99	1.97	1.30	66.85	69.47	0.90	1.47	0.11	8.37	21.18	1.98	0.81	8.91	2.07	3.02	0.94
Y117-86-03	2.07	1.16	66.89	84.40	2.14	4.77	0.92	9.62	11.90	7.22	0.66	5.26	1.05	7.62	1.25
Y117-91-03	1.44	1.00	70.23	65.13	1.00	1.41	0.64	5.26	14.03	3.17	0.48	9.08	0.78	4.08	2.62
Y121-42-99	1.65	0.94	58.00	82.95	4.59	2.59	1.64	2.99	12.71	11.99	0.11	5.49	0.37	3.08	1.39

Horticultural Discussion of RVT

The relatively compact period of average bloom dates of genotypes in the RVTs indicates that the California almond industry cannot count on the genotypes in these trials to substantially expand the bloom/pollination window for almonds in California. This expanded bloom period could be advantageous for spreading the risk of adverse weather (prolonged rains and cold weather) that could impact bee flight hours. Further, expanding the bloom window could reduce the risk of spring frosts impacting flight hours during the highly sensitive periods during and immediately after bloom. There are almond varieties from other countries' programs (particularly Spain) that are later blooming than varieties in California. However, if the late blooming trait is linked to a higher chilling requirement, this factor must also be considered as winter periods are likely to continue to become warmer.

The percent crack-out of kernels in the RVTs ranged from 35- 80%. The newer selections in the trials ranged from 45-70% and most were above 50%. This indicates that California almond breeding programs are apparently selecting for a high crack-out percentage. There appeared to be a general inverse relationship between crack-out percentage and percent shell seal among many of the varieties, but there were some exceptions such as 2-19E Kester/Hansen. Good shell seal could be advantageous in the industry's ongoing effort to combat Navel Orangeworm (NOW). It is also interesting that rootstock appeared to have a strong effect on percent crack-out of the Kester variety but much less effect on shell seal. Two varieties (Eddie and Bennett) and three selections (UCD 8-27, UCD 1-16, UCD 1-271) clearly scored on the lower end of the range on shell seal.

Percent double kernels is a significant defect for certain sectors of almond marketing and only three cultivars scored above 7% while five selections were above 7%. Breeders may need to pay more attention to this trait as it negatively affects almond quality.

Trees in the Madera trial had higher kernel yields earlier than the other two sites. Some of this is due to higher tree density but probably also is due to faster tree development. Kernel yields when the trees neared maturity in 2018 and 2019 were higher in the Butte and Madera trial compared to the Stanislaus trial. Much of these differences can be attributed to the fact that trees in Butte and Madera were larger and intercepted more light than trees in the Stanislaus trial. Interestingly, the top producing varieties in Stanislaus tended to have slightly more kernel weight per unit of intercepted light than in the other two trials.

The data generated in these regional variety trials show clear differences in the performance of the multiple varieties and selections. Even though the data presented here should be considered preliminary as there have been only five years of yield data, and two years of near-mature yield data, there is still enough data to help determine which genotypes are not commercially viable. For further clarification on the use of these varieties/selections, a stability analysis should be performed to better evaluate the mean performance over multiple environments. This will be discussed more at the end of this report.

Part II: Varieties & Selections Not Part of Current RVT

Among the varieties included in the 2019 Crack-Out event were a number of international varieties and new selections from private breeders in California that are not part of the current RVT. These derive from the following sources:

- **IRTA:** Institute of Agrifood Research and Technology, Lleida, Spain
    - Breeder: Ignasi Batlle
- **CITA:** Aragon Agrifood Research and Technology Center, Zaragoza, Spain.
    - Breeder: Maria Jose Rubio
- **CEBAS-CSIC:** Centro de Edafologia Biologia Aplicada del Segura- Consejo Superior De Investigaciones Cientificas, Murcia, Spain.
    - Breeder: Federico Dicenta
- **Volcani Center:** Agricultural Research Organization, Rishon LeTsiyon, Israel.
    - Breeder: Doron Holland
- **University of Adelaide Breeding Program:** Adelaide, Australia.
    - Breeder: Michelle Wirthensohn
- **Zaiger Genetics:** Modesto, CA
    - Breeder name: Grant Zaiger
- **Burchell Nursery:** Oakdale, CA
    - Breeders: Tom Burchell and John Slaughter

The data presented here comes from published literature as well as from information provided by the breeders. The tables below summarize information from the even (**Table II-1-7**):

Table II-1. Horticultural traits for five U.S. varieties compared to Nonpareil. These data is self-reported by private breeders and nurseries.

Variety	Vigor	Growth Habit	Bloom time vs NP	Self-compatibility	Harvest
Independence	moderate	upright to spreading	+0d	Yes	Early (-2-3d NP)
Nonpareil	high	upright to spreading	+0d	No	early
Peerless	moderate	semi-upright	-2d NP	No	mid-late (+16d NP)
Pyrenees	moderate	open	+3d NP	Yes	late-mid (+14-21d NP)
Shasta	moderate	semi-upright to spreading	+0d NP	Yes	Early (-3-5d NP)
Z5R754	moderate	mid upright to spreading	+5d NP	Yes	mid-late (+10-15d NP)

Table II-2. Horticultural data for 18 Spanish varieties compared to Nonpareil. Information based on international research. Results for environmental conditions in California need to be confirmed. Rlb = red leaf blotch. Desmayo Largueta bloom date is very early. Data provided by almond breeders, Ignasi Battle at IRTA, Federico Dicenta at CEBAS-CSIC, and Maria Jose Rubio Cabetas at CITA.

Spanish Varieties	Location	Vigor	Growth Habit	Branching density	Bloom time	Self-compatible ?	Harvest
Nonpareil	U.S.	high	upright to spreading	medium	mid	No	early
Constanti	IRTA	high	medium-upright	medium	late	Yes	medium (end Aug)
Marinada	IRTA	medium	medium-upright	medium-scarce	Very late (+ 33d Desmayo Largueta)	Yes	medium (early Sept)
Tarraco	IRTA	medium	medium-erect	medium-scarce	Very late (+ 35d Desmayo Largueta)	No	medium-
Vairo	IRTA	high	medium	medium	late	Yes	early (mid-late Aug.)
Selection '29-148'	IRTA	medium		medium	very late	Yes	early (early Sept.)
Selection '30-297'	IRTA	high		medium-low	very late	Yes	late (mid-Sept)
Belona	CITA	medium	semi-opening		late	Yes	medium
Guara	CITA	very high	open, weeping	average-scarce	late	Yes	early (mid Aug.)
Mardia	CITA		slightly semi-opening	medium	extra late (+25 d NP)	Yes	early
Soleta	CITA	medium	semi-opening		late	Yes	medium-late
Vialfas	CITA	low		intermediate	extra late (+22d NP)	Yes	early
Antoneta	CEBAS-CSIC	high	open	abundant	late (+8d NP)	Yes	early (-1d NP)
Makako	CEBAS-CSIC	high	balanced	abundant	extra late (+24d NP)	Yes	intermediate (+13d NP)
Marta	CEBAS-CSIC	high	upright	balanced	late (+8d NP)	Yes	early (+3d NP)
Penta	CEBAS-CSIC	inter-mediate	balanced	abundant	extra-late (+26d NP)	Yes	early (+7d NP)
Selection 'D00-360'	CEBAS-CSIC	high	balanced	balanced	extra late (+21d NP)	Yes	early (+4d NP)
Selection 'D01-188'	CEBAS-CSIC	high	balanced	balanced	early (+0d NP)	Yes	very early (-3d NP)
Selection 'D06-795'	CEBAS-CSIC	inter-mediate	balanced	balanced	extra-late (+19d NP)	Yes	intermediate (+16 NP)

Table II-3. Horticultural traits for six Australian varieties compared to Nonpareil. Information based on international research. Results for environmental conditions in California need to be confirmed.

Varieties	Parentage	Vigor	Growth Habit	Bloom time	Bloom length	Self-Compatible?	Bacterial spot tolerance	Harvest
Nonpareil		high	upright to spreading	early	3-4 weeks	No		mid
Capella	Nonpareil × Lauranne	medium - high	dense	medium (NP + 2d)	4 weeks	Yes	4.5/5	early-mid
Carina	Nonpareil × Lauranne	low - medium	spreading	early (NP - 4d)	4 weeks	Yes	5.0/5	early
Maxima	Nonpareil × Lauranne	very high	spreading	medium (NP + 4d)	3 weeks	No	under study	early-mid
Mira	Nonpareil × Lauranne	vigorous	slightly open	medium (NP + 3-5d)	3 weeks	Yes	2.5/5	early-mid
Rhea	LeGrand × Keanes	vigorous	slightly open	early-mid NP - (3-4d)	3 weeks	No	under study	mid
Vela	Chellaston × (Nonpareil × Lauranne)	medium	upright to spreading	early mid (NP - 3d)	3 weeks	Yes	4.5/5	mid-late

Table II-4. Almond quality data for five U.S. varieties not in the current RVTs compared to Nonpareil. Data taken from the Almond Board of California, Almond Production Manual[2], nutritional analysis from Yada et al. 2013[3], King et al. 2019[4], and Zaiger Genetics[5] and Burchell Nurseries[6].

Variety	Shell text.	Suture opening	Pellicle color	Kernel texture	Kernel shape	Kernel size
Independence	soft	high	light	smooth	long flat	medium
Nonpareil	soft	high	light	smooth	flat	medium
Peerless	hard	high	light	wrinkled	short wide	medium
Pyrenees	semi-hard	low	light	smooth	long	medium
Shasta	soft	low	light	smooth	large, flat	large
Z5R754	soft	TBD	light-med.	lightly wrinkled	long	medium

[2] Micke, Warren C. 1996. Almond production manual. Berkeley [etc]: University of California.
[3] Sylvia Yada, Guangwei Huang, Karen Lapsley, Natural variability in the nutrient composition of California-grown almonds, Journal of Food Composition and Analysis, Volume 30, Issue 2, 2013, Pages 80-85.
[4] King ES, Chapman DM, Luo K, Ferris S, Huang G, Mitchell AE. Defining the Sensory Profiles of Raw Almond (Prunus dulcis) Varieties and the Contribution of Key Chemical Compounds and Physical Properties. J Agric Food Chem. 2019;67(11):3229-3241.
[5] Personal Communication with Zaiger Genetics on 5/6/2020.
[6] Personal Communication with Burchell Nurseries on 4/14/2020.

Table II-5. Almond quality data for 18 Spanish varieties compared to Nonpareil. Information based on international research. Results for environmental conditions in California need to be confirmed. Data provided by almond breeders, Ignasi Battle at IRTA, Federico Dicenta at CEBAS-CSIC, and Maria Jose Rubio Cabetas at CITA. Chemical analysis from (Kodad et al. 2015). Kodad, O., Anson, J. M., Alonso, J. M. (2015). 'Vialfas' Almond. HortScience, 50(11), 1726-1728.

Spanish Varieties	Location	Shell texture	Crack-out (%)	Doubles (%)	Pellicle color	Kernel wt (g)	Oil (%)	Oleic (%)	Linoleic (%)	Protein (%)	Soluble sugars (%)	Total fiber (%)	Water (%)
Nonpareil	U.S.	soft	66	2.7	light	1.2	60.5	67.7	23.3	13.0	4.1	12.9	3.9
Constanti	IRTA	hard	27	1.1		1.2	53.2			23.9	2.6	9.3	4.4
Marinada	IRTA	hard	31	0.3	light	1.3	47.9			24.2	4.1	11.2	4.8
Tarraco	IRTA	hard	32	0.1		1.7	53.4			24.6	2.9	9.3	4.7
Vairo	IRTA	hard	29	0.1		1.2	52.7			24.5	3.0	9.0	4.6
Selection '29-148'	IRTA	semi-hard	39	0		1.3	60.2			22.7	2.8	7.8	2.7
Selection '30-297'	IRTA	hard	28	0.3		1.6	57.1			27.6	3.2	6.4	2.3
Belona	CITA	hard	27 - 35	0		1.3	65.4	75.6	12.7	16.4		4.4	
Guara	CITA	hard	30 - 34	10 - 20			54.3	63.1	25.7	29.3		4.6	
Mardia	CITA	hard	24	0		1.2	59.1	74.9	16.5	19.8		5.5	
Soleta	CITA	hard	27 - 35	0		1.3	61.8	69.2	19.7	20.0		4.8	
Vialfas	CITA	hard	22	0		1.2	57.4	77.9	12.3	18.8		5.6	
Antoneta	CEBAS-CSIC	hard	35	0	light	1.5	54.9	72.6	19.4	21.6	3.7	11.6	4.5
Makako	CEBAS-CSIC	hard	30	0	intermediate	1.2	56.9	72.4	20.1	21.1	4.4	9.1	4.1
Marta	CEBAS-CSIC	hard	32	0	intermediate	1.2	57.7	72.9	17.4	20.9	3.1	10.3	3.8
Penta	CEBAS-CSIC	hard	30	0	light	1.0	56.1	71.7	21.0	20.8	4.6	9.9	4.7
Selection 'D00-360'	CEBAS-CSIC	semi-soft	39	2.0	light	1.0	54.3	72.2	20.1	22.0	4.9	10.2	4.4
Selection 'D01-188'	CEBAS-CSIC	soft	48	2.0	light	1.4	56.6	71.8	20.3	21.3	4.4	9.5	3.9
Selection 'D06-795'	CEBAS-CSIC	soft	52	2.0	intermediate	1.2							

Table II-6. Almond quality data for six Australian varieties compared to Nonpareil. Information based on international research. Results for environmental conditions in California need to be confirmed.

Varieties	Nut shape	Kernel Size (g)	Crack-out (%)	Shell texture	Pellicle color	Doubles	Oil (%)	Oleic Acid (%)
Nonpareil	flat	1.20	63.0	paper-shell	light	few	49.6	67.7
Capella	ovate	1.33	26.1	hard	light	none	53.0	67.0
Carina	ovate	1.34	41.1	semi-hard	light	none	57.4	62.3
Maxima	cordate	1.81	30.2	semi-hard	light, bright	none	62.4	59.9
Mira	cordate	1.28	43.5	semi-hard	light	none	61.3	59.3
Rhea	cordate	1.28	58.1	paper	light	none	54.7	67.5
Vela	cordate	1.70	53.0	soft-shell	med - light	none	51.3	64.2

Table II-7. Pomological traits and almond quality data for the Israel variety 'Matan' compared to Nonpareil. Information based on international research. Results for environmental conditions in California need to be confirmed.

Variety	Growth habit	Productivity	Self-Compatible?	Shell texture	Pellicle color	Crack-out (%)	Kernel size (g)	Kernel length (cm)	Kernel width (cm)	Doubles
Nonpareil	upright, spreading	high	No	soft-shell	light brown	66	1.2	2.4	1.3	few
Matan	balanced	good	Yes	semi-hard	light brown	48	1.48	2.9	1.6	very few

Horticultural Discussion of Non-RVT Varieties

From the U.S. varieties, Independence, Shasta, Selection 5ZR754, and Pyrenees are self-compatible. Independence has received wide industry adoption while Shasta and Pyrenees are in their early years of commercialization. Independence and Shasta are harvested on similar dates as Nonpareil, which implies that there could be a narrow window of harvesting and processing time in the years to come. We see an opportunity to develop varieties whose harvest date is earlier than Nonpareil (could avoid third flight of NOW), or around two weeks after Nonpareil (such as Pyrenees or 5ZR754). In addition, all these self-compatible varieties show less vigor than Nonpareil, which brings an opportunity to evaluate their performance under off-ground harvest systems in combination with slightly higher tree densities and dwarfing rootstocks.

The Guara variety was the first self-compatible variety developed in Spain in 1987, before molecular markers were adopted in the Spanish breeding programs. In the late 1990s to early 2000s, marker-assisted selection sped up the identification of self-compatible varieties, and as result 17 out of the 18 Spanish varieties presented in this report are self-compatible. While Guara has been commercially planted in California by a handful of California growers, it remains unknown how the new Spanish selections will perform under California conditions.

The new Spanish selections represent two or three generations of self-compatible efforts and include new traits such as late bloom dates. In fact, most of the Spanish varieties seem to bloom between eight and 35 days after Nonpareil, which mitigates the risk of frost events. However, most of these selections are hard shell, which makes them less attractive for California processing conditions. On the other hand, three new selections from CEBAS are soft shell, have a crack-out between 39% and 52%, are self-compatible, and are theoretically harvested under California conditions between -3 and 16 days after Nonpareil. Similarly, the semi-hard-shell selection (29-148) from IRTA has a crack out of 39% and also looks promising for California growing and processing conditions as this selection is self-compatible, late blooming, and is theoretically harvested at a similar date to Nonpareil.

The six Australian varieties presented in this report seem to bloom around the same time as Nonpareil. Four of these varieties are self-compatible, while Rhea and Maxima are not. From the self-compatible varieties, Capella, Carina, and Vela show less vigor than Nonpareil, which makes them attractive for off-ground harvesting. Vela and Rhea are soft shell and have crack-out percentages similar to Nonpareil (58% and 53%, respectively). However, Rhea is not self-compatible, thus Vela is potentially a better candidate to be evaluated in California. In addition, Vela is theoretically harvested after Nonpareil, which could help to open the window of operations around that time.

Finally, the semi-hard and self-compatible variety from Israel named Matan has a crack out of 48%. This relatively high crack-out percentage for a semi-hard variety is probably due to the big kernel size produced by this variety (1.48g). More critical information such as bloom date, and harvest time should be obtained from this variety before further evaluation.

Part III: Crack-Out Data, Hedonic Analysis, and Sensory Evaluations on All Varieties and Selections

Nut samples from 64 varieties and selections from the U.S., Australia, Spain, and Israel were collected and prepared for the Crack-Out event in November 2019. Shelled and inshell samples were prepared for display and comparatively evaluated.

Nonpareil is used as a parent in the breeding program at University of Adelaide and therefore the Australian varieties are more similar in characteristics to U.S. varietals, compared to the predominantly hard-shell varieties preferred in Spain. Most varietals represented from Spain, Australia and Israel are now self-compatible. Several self-compatible U.S. varietals are either available commercially or in the pipeline from both public and private breeders.

A. Crack-Out Data

Quantitative measures of kernel dimensions are displayed in **Figures III-1-3**. Kernel length ranged between 6.7 mm – 9.4 mm (SD = 3.2, mean = 24.02). There were no statistically significant relationships between source and kernel lengths. UCD 18-20 kernels were the longest (38.2 mm) while Selection 00-360 kernels were the shortest (19.35 mm). Kernel width ranged between 19.35 mm and 38.1 mm (SD = 1.47, mean = 13.61). There were also no statistically significant relationships differences between source and kernel widths. Both Antoneta and Self-Fruitful P16.013 had the largest kernel widths (16.80 mm), while UCD 8-27 had the smallest kernel width. Kernel thickness ranged between 10.9 mm – 17.6 mm (SD = 0.63, mean = 8.02). There were statistically significant relationships differences observed between kernel thickness and source (Spain-IRTA $p < 0.05$, U.S. $p < 0.01$). Selection UCD 7-159 had the greatest kernel thickness (9.4 mm), while Vialfas was the thinnest (6.7 mm).

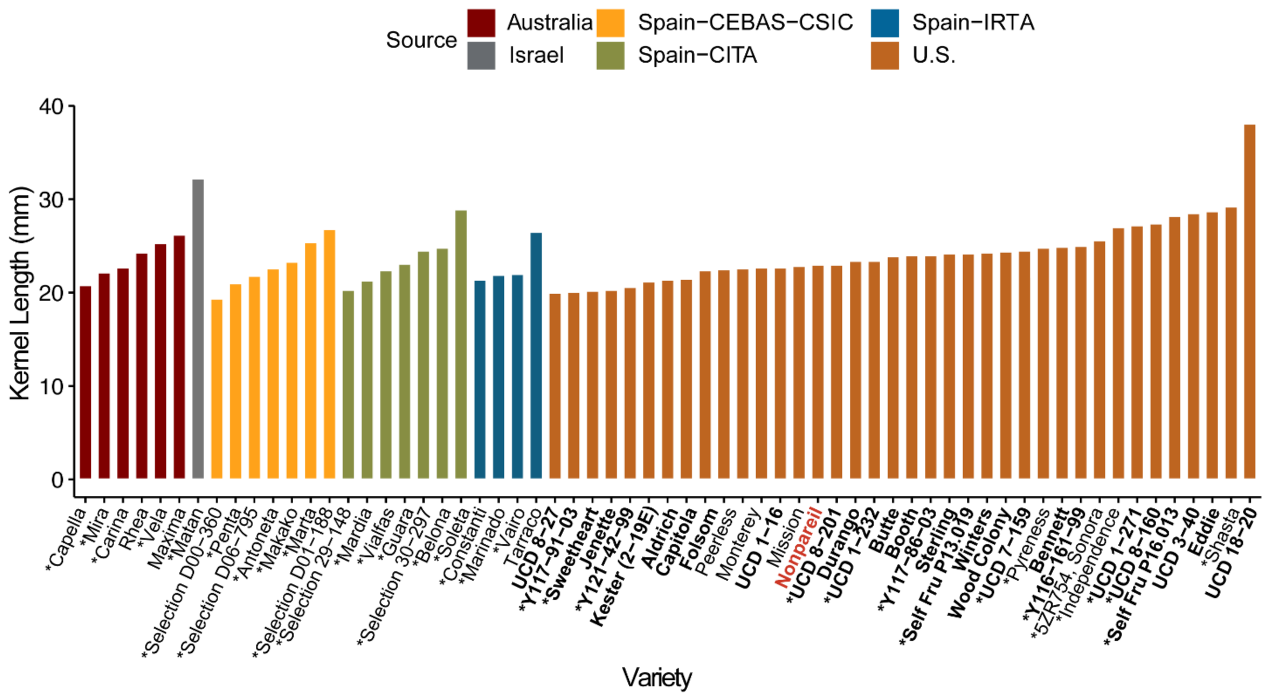


Figure III-1. Kernel length measured for 64 varieties/selections. Varieties that have a "*" are self-compatible. RVT genotypes are in bold.

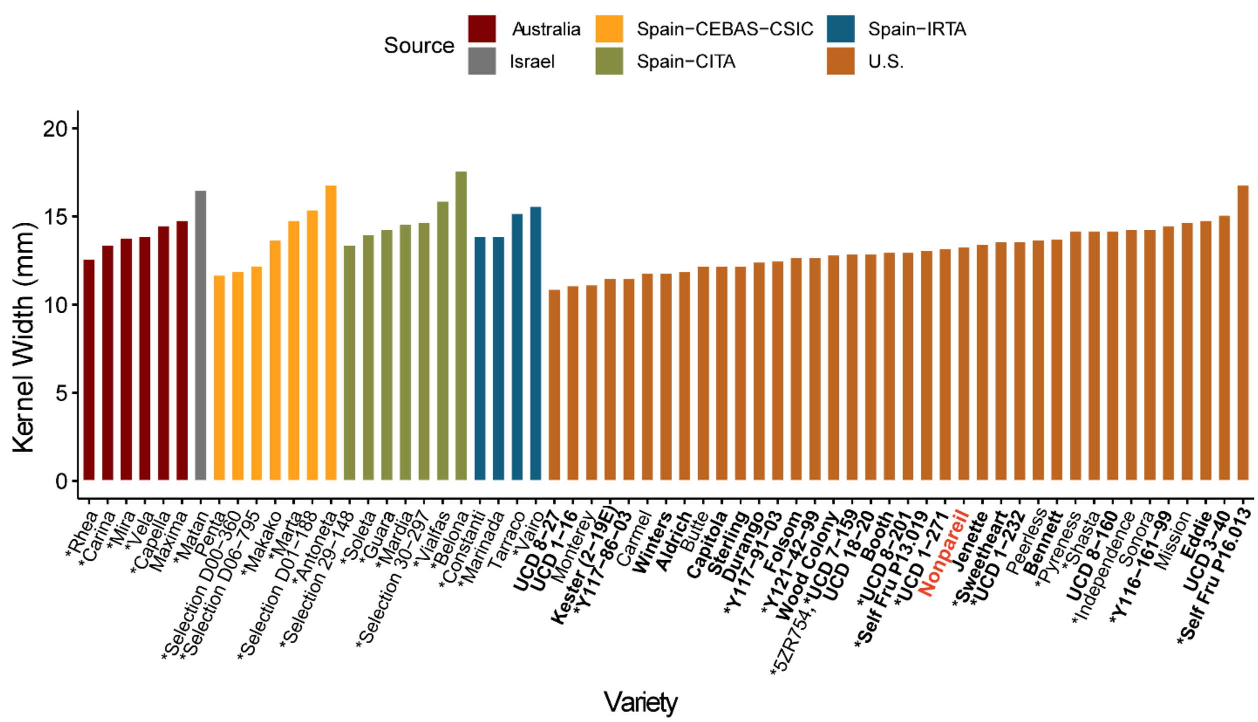


Figure III-2. Kernel width measured for 64 varieties/selections. Varieties that have a "*" are self-compatible. RVT genotypes are in bold.

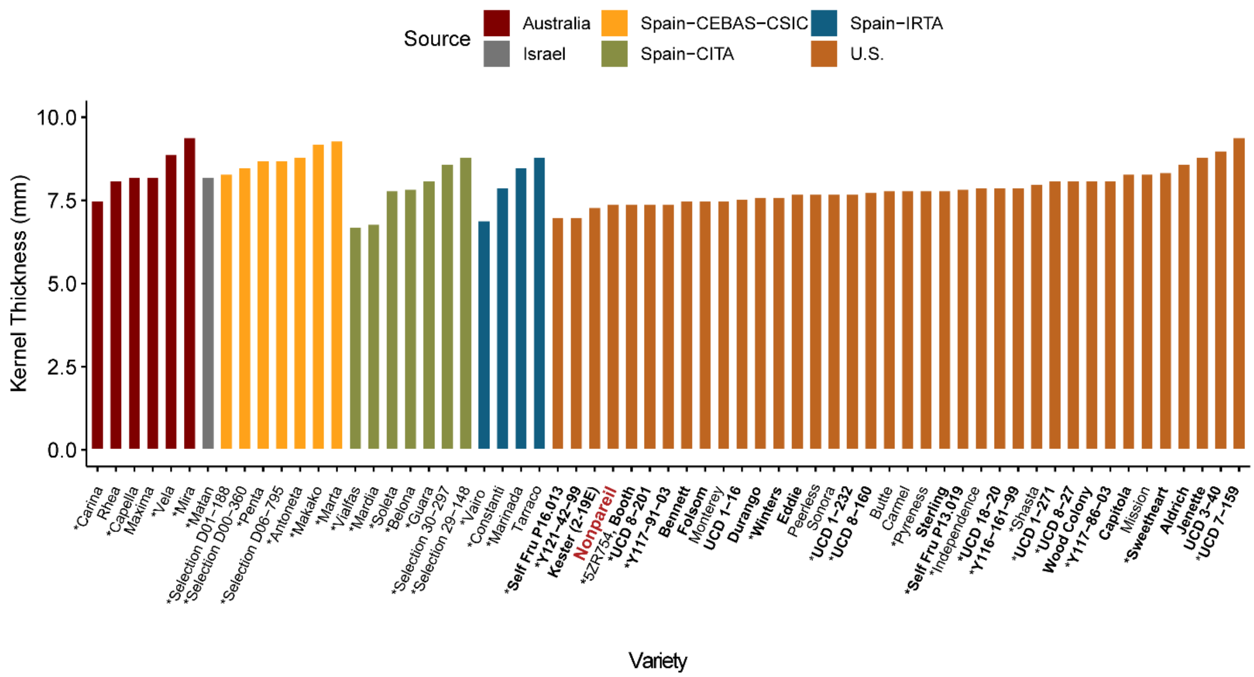


Figure III-3. Kernel thickness measured for 64 varieties/selections. Varieties that have a "*" are self-compatible. RVT genotypes are in bold.

Crack-out or shelling percentage (kernel mass ÷ total shell and kernel mass) (**Figure III-4**) was above 50% for soft-shell varieties; U.S. (Sonora, Nonpareil, Carmel, Pyrenees, Shasta, Independence, 5ZR754, Bennett, Jenette, etc); Australian (Rhea, Vela); Spanish (Selection D06-795). In contrast, hard-shell varieties under 30% were Spanish (Selection 30-297, Constanti, Soleta, Mardia, Vialfas) and Australian (Capella).

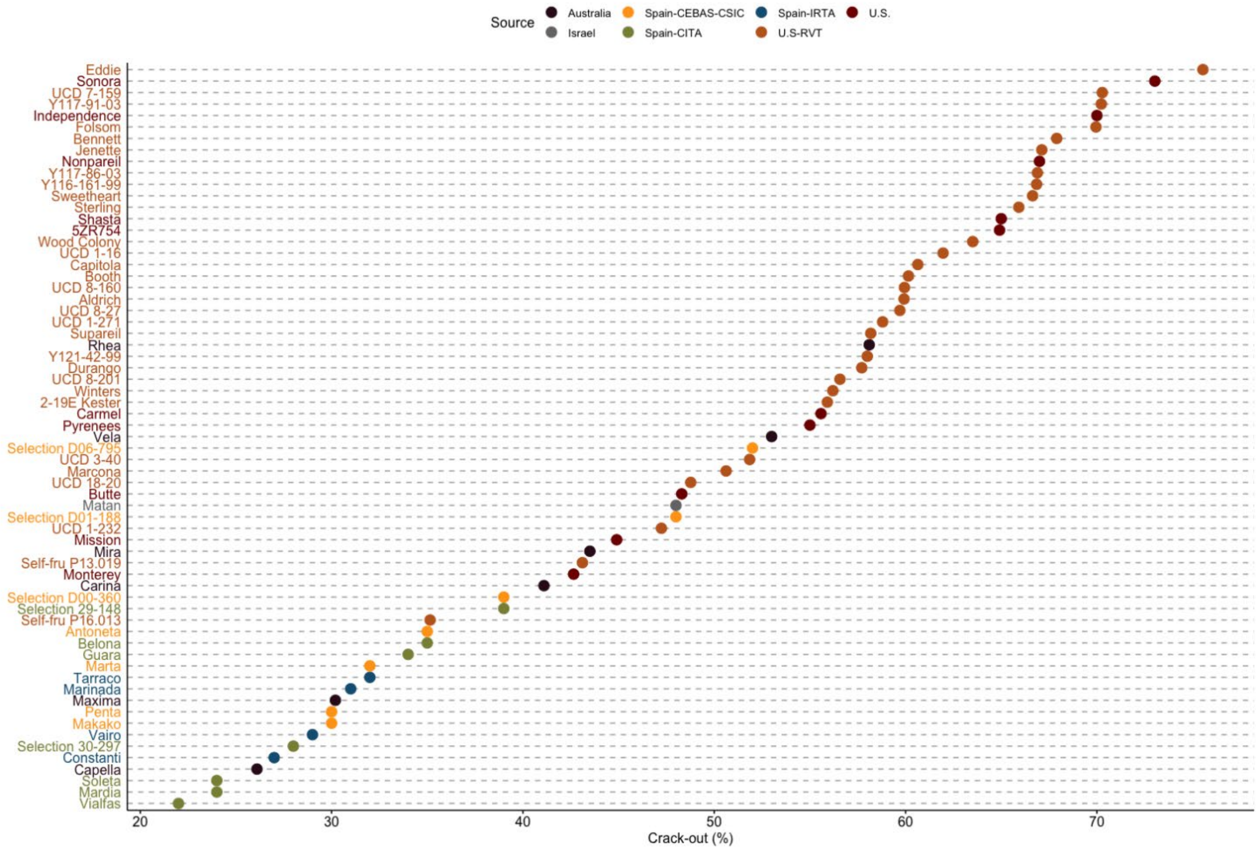


Figure III-4. Crack-out percentage (kernel mass ÷ total shell and kernel mass) for 64 of the varieties/selections from the Crack-Out event. Data based on reports by breeders and data collected in the RVTs. These results should be viewed as preliminary since only 50 kernels per variety were used to generate this data.

Almond pellicle (kernel skin) color was rated and the varieties were separated into five categories. Nonpareil was considered “light” along with many U.S. varieties (Aldrich, Eddie, Independence, Self-Fruitful P13.019, Shasta, Sonora, Sterling, UCD 1-271, etc.), and all USDA varieties. All the Australian varieties were rated as either “light” or “medium light.” The Spanish varieties ranged from “light” to “dark colored.” The only “dark” U.S. variety was Jenette **(Table III-1).**

Almond texture was rated, and varieties were separated into seven categories (**Table III-1**). Nonpareil was categorized as possessing a “smooth” surface, along with some U.S. varieties (Self-Fruitful P16.013, Shasta, Sonora, Sterling, UCD 1-271, UCD 8-27) while several other U.S. varieties (Booth, Capitola, Kester and Monterey) were categorized as having “deep wrinkles”. All Australian varieties were rated as being in the “smooth” or “light wrinkle” categories except for Capella, which had “deep” wrinkles. The Spanish varieties were distributed among all the texture categories.

Almond varieties were separated into seven categories with regard to shell thickness (**Table III-1**). Nonpareil was categorized as having a “thin shell”, and only U.S. varieties were in the thin category (Aldrich, Bennett, Folsom, Jenette, Sonora, Sterling, UCD 7-159, UCD 8-27, UCD 8-160, Y117-86-03, Y117-91-03, 5ZR754, Eddie, and Independence). Several varieties from Spain (Constanti, Terraco, Vairo, Guara, Mardia, Soleta, Antoneta, Makako, Penta), one each from Australia (Capella) and Israel (Matan) and several from the U.S. (Peerless, Self-Fruitful P16.013, UCD 1-271, UCD 3-40) were in the “thick” category. Three Spanish varieties (Belona, Vialfas, Marta) had shells in the very thick category. Thus, the preponderance of varieties from Spain were thick while Australia and the US had multiple varieties in the “medium” shell thickness categories. Three Australian varieties were in the “medium thin” category (Carina, Rhea, Vela) along with three US varieties (Winter, Capitola, Sel D06-795).

Table III-1. Physical characteristics (shell thickness, kernel color, and kernel texture) of varieties presented during the Crack-Out event. These results should be viewed as preliminary since only 50 kernels per variety were used to generate this data.

Cultivar	Source	Shell Thickness	Kernel Color	Kernel Texture
Nonpareil	U.S.	thin	light	smooth
Aldrich	U.S.	thin	light	light-medium wrinkle
Bennett	U.S.	thin	light-medium	light wrinkle
Booth	U.S.	medium	medium	deep wrinkle
Butte	U.S.	medium	medium	light wrinkle
Capitola	U.S.	thin-medium	medium	deep wrinkle
Carmel	U.S.	medium	medium	light wrinkle
Durango	U.S.	medium	medium	light wrinkle
Eddie	U.S.	thin (very)	light	light wrinkle
Folsom	U.S.	thin	light-medium	medium wrinkle
Independence	U.S.	thin (very)	light	light wrinkle
Jenette	U.S.	thin	dark	medium-deep wrinkle
Kester (2-19E)	U.S.	medium	medium	deep wrinkle
Mission	U.S.	medium	medium-dark	medium-deep wrinkle
Monterey	U.S.	medium	medium-dark	deep wrinkle
Peerless	U.S.	thick	medium-dark	smooth-light wrinkle
Pyreness	U.S.	medium	medium	smooth-light wrinkle
Self Fruit P13.019	U.S.	medium	light	medium wrinkle
Self Fruit P16.013	U.S.	thick	light-medium	smooth
Shasta	U.S.	medium	light	smooth
Sonora	U.S.	thin	light	smooth
Sterling	U.S.	thin	light	smooth
Sweetheart	U.S.	medium	medium	medium wrinkle
UCD 1-16	U.S.	medium	light-medium	smooth-light wrinkle
UCD 1-232	U.S.	medium	medium-dark	medium wrinkle

Cultivar	Source	Shell Thickness	Kernel Color	Kernel Texture
UCD 1-271	U.S.	thick	light	smooth
UCD 3-40	U.S.	thick	medium	light wrinkle
UCD 7-159	U.S.	thin	medium-dark	smooth-light wrinkle
UCD 8-27	U.S.	thin	medium-dark	smooth
UCD 8-160	U.S.	thin	light-medium	light-medium wrinkle
UCD 8-201	U.S.	medium	light-medium	light wrinkle
UCD 18-20	U.S.	medium-thick	medium-dark	light-medium wrinkle
Winters	U.S.	thin-medium	medium-dark	light wrinkle
Wood Colony	U.S.	medium	medium-dark	medium wrinkle
Y116-161-99	U.S.	medium	light	light wrinkle
Y117-86-03	U.S.	thin	light	light wrinkle
Y117-91-03	U.S.	thin	light	smooth-light wrinkle
Y121-42-99	U.S.	medium	light-medium	medium wrinkle
5ZR754	U.S.	thin	light-medium	light wrinkle
Capella	Australia	thick	light	deep wrinkle
Carina	Australia	thin-medium	light	smooth-light wrinkle
Maxima	Australia	medium-thick	light-medium	light-medium wrinkle
Mira	Australia	medium-thick	light	smooth
Rhea	Australia	thin-medium	light-medium	smooth-light wrinkle
Vela	Australia	thin-medium	light-medium	smooth-light wrinkle
Constanti	Spain-IRTA	thick	medium	light wrinkle
Marinada	Spain-IRTA	medium-thick	medium	light wrinkle
Tarraco	Spain-IRTA	thick	dark	light wrinkle
Vairo	Spain-IRTA	thick	light	smooth-light wrinkle
Selection 29-148	Spain-CITA	medium-thick	light	light-medium wrinkle
Selection 30-297	Spain-CITA	thick	light	medium-deep wrinkle
Belona	Spain-CITA	thick (very)	light-medium	medium wrinkle
Guara	Spain-CITA	thick	light	smooth-light wrinkle

Cultivar	Source	Shell Thickness	Kernel Color	Kernel Texture
Mardia	Spain-CITA	thick	medium-dark	deep wrinkle
Soleta	Spain-CITA	thick	medium	smooth
Vialfas	Spain-CITA	thick (very)	light-medium	deep wrinkle
Antoneta	Spain-CEBAS-CSIC	thick	medium	medium wrinkle
Makako	Spain-CEBAS-CSIC	thick	light-medium	medium wrinkle
Marta	Spain-CEBAS-CSIC	thick (very)	medium	medium wrinkle
Penta	Spain-CEBAS-CSIC	thick	medium	smooth
Selection D00-360	Spain-CEBAS-CSIC	thick	medium-dark	deep wrinkle
Selection D01-188	Spain-CEBAS-CSIC	medium	light	medium wrinkle
Selection D06-795	Spain-CEBAS-CSIC	thin-medium	medium	medium-deep wrinkle
Matan	Israel	thick	medium	smooth-light wrinkle

One of the key measurements is the "crack-out" or shelling percentage since it is often thought that it influences the kernel yield potential of a variety because the percentage of carbon that the tree puts into shells relative to kernels is one indicator of kernel production efficiency. Thus, it is often thought that varieties with higher crack-outs have the potential to have higher kernel yields (other things being equal). A rough comparison of the shell thickness ratings (Table III-1) with the crack-out data (Figure III-4) indicates that crack-out is roughly related to shell thickness.

Shell thickness and shell seal may also be important as an indicator of relative vulnerability of kernels to insect pests like NOW. At present, thin-shelled varieties are favored for the purposes of processing, but in the future, as pest control measures are more tightly controlled, having varieties with less penetrable shells may be an advantage.

Kernel size and dimensions influence the suitability of specific varieties for certain markets or industrial purposes. Some varieties with specific traits are preferred over others and appear to be based more on industry standards rather than horticultural issues. Texture, deepness of wrinkles and kernel color can have potential effects on consumer preference or industrial uses that require blanching, for example.

B. Hedonic Analysis and Sensory Evaluations

The hedonic and sensory evaluations were conducted by attendees at the Crack-Out event. Over seventy industry professionals ranging from scientists, breeders, nurserymen, growers and processors participated.

A hedonic scale is a nine-point ordinal scaling system with simplified descriptors that evaluate the degree of like/dislike of a particular sample. **Table III-2** lists each descriptor and its coordinating assigned value used in this study.

Table III-2. Hedonic scale with corresponding descriptor used in sensory analysis.

Scale	Descriptor
1	Dislike Extremely
2	Dislike Very Much
3	Dislike Moderately
4	Dislike Slightly
5	Neither Like nor Dislike
6	Like Slightly
7	Like Moderately
8	Like Very Much
9	Like Extremely

Sensory characteristics where measured using this hedonic scale for the following sensory aspects:

- Appearance – first attribute perceived (i.e., shape, color, uniformity, free of defects)
- Aroma and Flavor:

Aroma: retro nasal perception of volatile compounds

Flavor: attribute that includes appearance, taste, aroma, texture and temperature

- Taste – chemical sensation; encompasses sweet and bitter in almond
- Texture – sense of touch (mechanoreceptors), astringency; “crisp” and “crunch” in an almond
- Market Potential – “Gut reaction” by the participant as to whether the variety has applications in the food industry
- Hedonic Sum – sum of all sensory measures per variety

Summary statistics were taken for each sensory measure (mean, standard deviation, minimum, maximum). Varieties were grouped accordingly into quartiles (four groups, each representing 25% of the samples) and subsequently graphed. Analysis of variance was carried out to determine statistically significant differences among hedonic scores with alpha = 0.05. Pearson correlation coefficients were calculated for sensory measurements. The Pearsons correlation is a method for measuring the relatedness to different traits.

For hedonic sums, varieties/selections with values greater than 30, representing the top 25%of the hedonic sum, are displayed in **Table III-3** and were from U.S. and Australia. A multiple mean comparisons statistical test (Tukey’s HSD) revealed significant differences in the hedonic sum among varieties where Spanish varieties such as Antoneta, Marta, Soleta, and Makako were distinct from U.S. varieties such as Bennett, Aldrich and Sonora (**Figure III-5**).

Table III-3. Top ranked varieties (total score >30) for the hedonic sum of all sensory measures listed in alphabetical order by variety name.

Variety	Source	Self-compatible?
Aldrich	U.S.	no
Bennett	U.S.	no
Butte	U.S.	no
Capitola	U.S.	no
Carina	Australia	yes
Durango	U.S.	no
Eddie	U.S.	no
Folsom	U.S.	no
Maxima	Australia	no
Mira	Australia	yes
Pyrenees	U.S.	yes
Rhea	Australia	no
Sonora	U.S.	no
Supareil	U.S.	no
UCD 1-16	U.S.	no
UCD 7-159	U.S.	yes
UCD 8-160	U.S.	yes
UCD 8-201	U.S.	yes
Y116-161-99	U.S.	yes
Y117-91-03	U.S.	yes
Y121-42-99	U.S.	yes

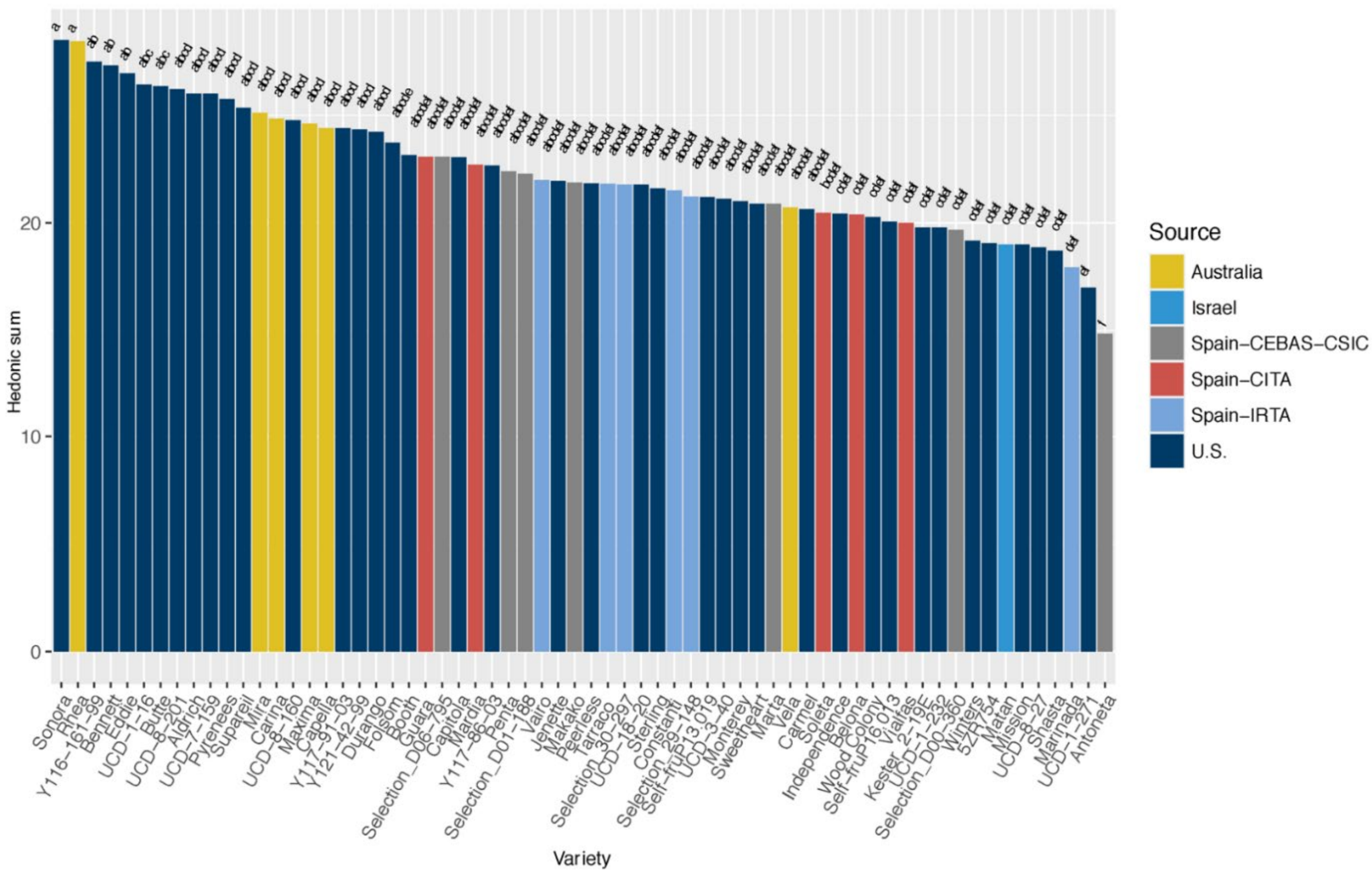


Figure III-5. Hedonic sums of all sensory measures. Varieties that do not have the same letters displayed above their vertical bars are significantly different according to a Tukey HSD test.

There was a strong correlation between aroma/flavor and taste (r = 0.75), and all sensory measures were correlated with the subjective evaluation of the market potential in this hedonic evaluation (r = 0.54 - 0.56) (**Figure III-6**). The fact that all the measurements were correlated with the market potential assessment illustrates the complexity of finding a variety with high market potential. In other words, this correlation analysis points out that a variety will score high in the "market potential" category only if most or all the other individual hedonic traits also received a high score.

For appearance, varieties originating from the U.S. and Australia with mean scores ranging from 7.24 - 7.93 (**Figure III-7**) were among the top ranked varieties. For aroma/flavor, the top scoring varieties were also from the U.S. and Australia with mean values of 6.77 – 7.28 (**Figure III-8**). In terms of taste, Mardia, a Spanish variety from CITA, was among the top ranked varieties, with a mean score of 6.59, SD = 1.37 (**Figure III-9**). For texture, panelists preferred only U.S. varieties, which had mean scores between 7.42 – 7.93 (**Figure III-10**). Finally, for the subjective evaluation of market potential in this hedonic analysis, U.S. varieties that were included in the RVT - Y116-161-99, Eddie, and UCD 1-16 were ranked highest, along with Rhea from Australia with mean scores ranging from 6.88 – 7.29 (**Figure III-11**).

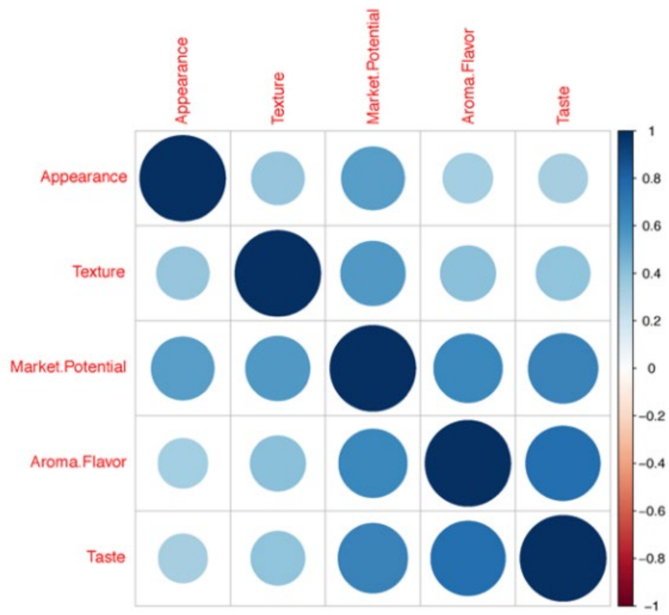


Figure III-6. Pearson's correlation of sensory measures. Scale of correlation (r) is displayed on the right-hand side with -1 having an inverse correlation and +1 having a positive correlation.

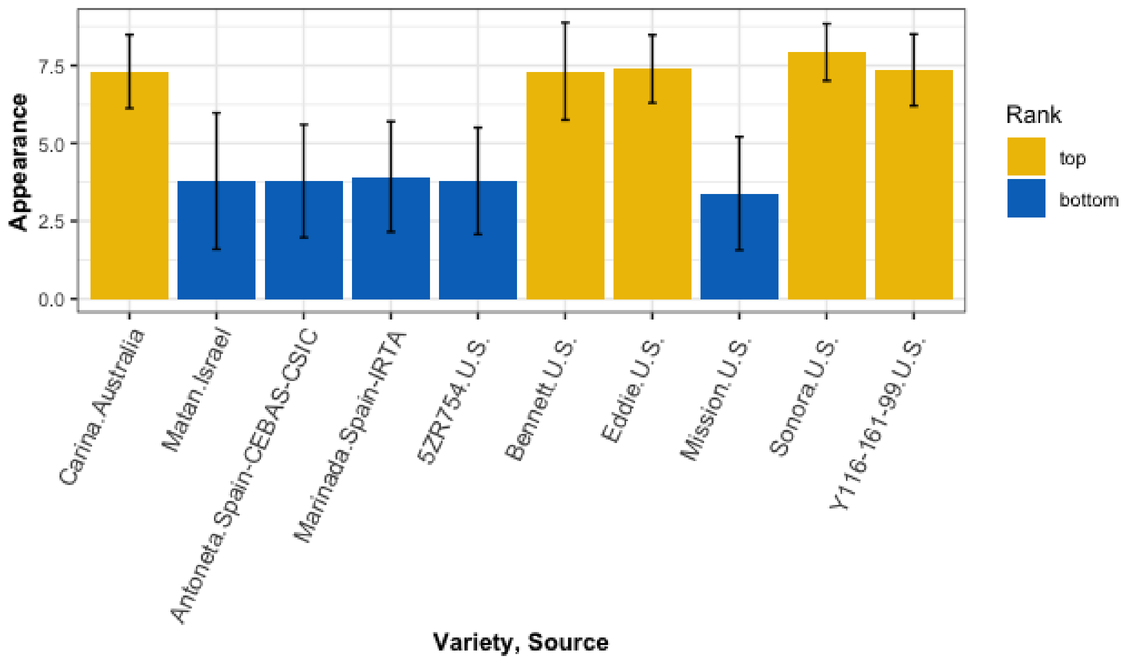


Figure III-7. Mean hedonic measure for appearance. Top and bottom ranked varieties are displayed (first and fourth quartile) with standard deviations.

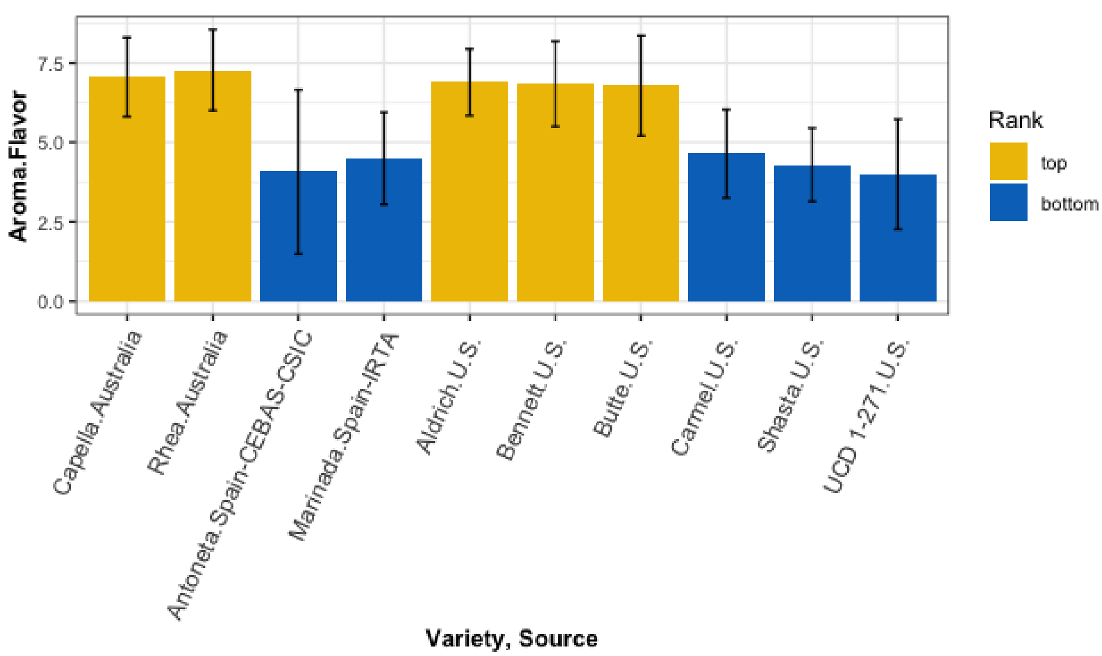


Figure III-8. Mean hedonic measure for aroma/flavor. Top and bottom ranked varieties displayed (first and fourth quartiles) with standard deviations.

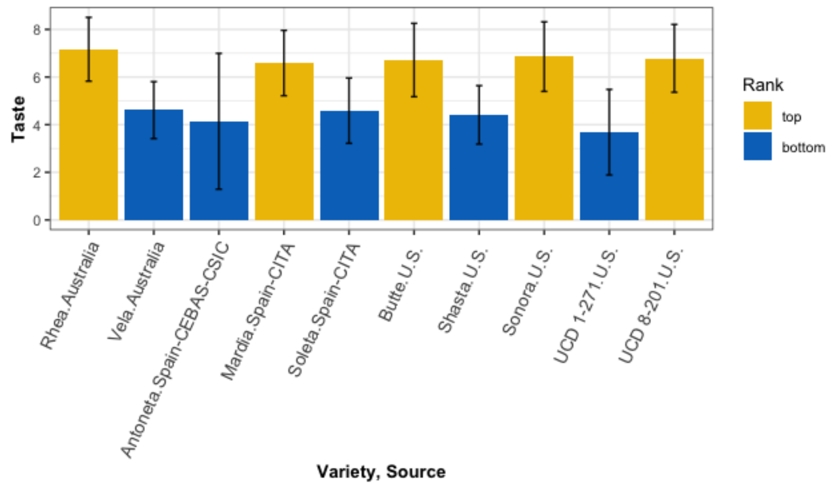


Figure III-9. Mean hedonic measure for taste. Top and bottom ranked varieties are displayed (first and fourth quantile) with standard deviations.

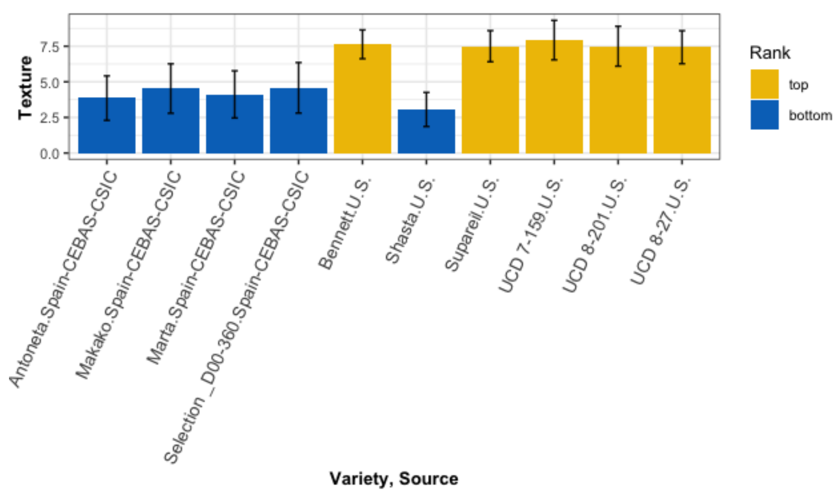


Figure III-10. Mean hedonic measure for texture. Top and bottom ranked varieties are displayed (first and fourth quartiles) with standard deviations.

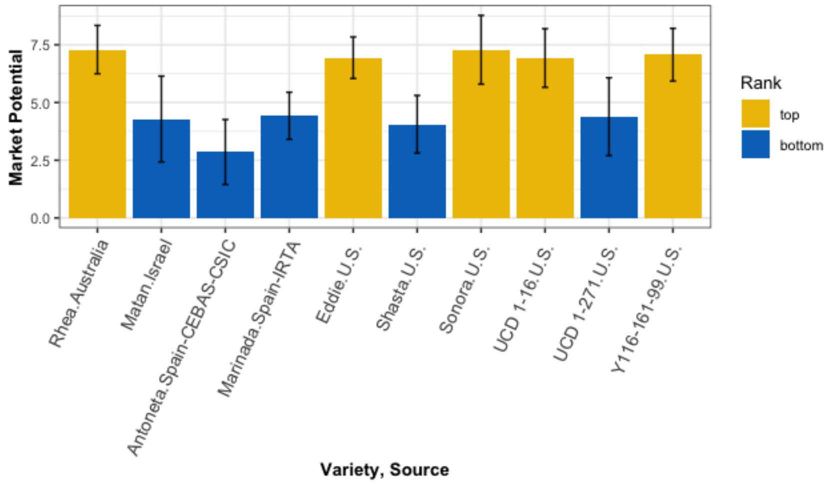


Figure III-11. Mean hedonic scores for market potential. Top and bottom ranked varieties are displayed (first and fourth quartiles) with standard deviations.

Discussion

This was the first pre-sensory evaluation of both international and domestic varieties in recent years, and as such, provides insights from across the industry to guide future variety development.

Sensory measurements such as aroma/flavor and taste were found to be highly correlated; both Rhea and Butte were ranked high in both categories. Texture scores should be considered preliminary since the moisture content of the samples was not strictly controlled.

Varieties originating from the U.S. and Australia ranked highest in all sensory categories, likely reflecting the preferences of the U.S industry. Attendees ranked Eddie and Y116-161-99 high in both market potential and appearance. Together, UCD 1-271 and Sonora were ranked high by panelists in both subjective market potential and taste. Bennett was ranked high in all the following: texture, appearance and aroma/flavor. Lastly for U.S. varieties, Butte was ranked high in both taste and aroma/flavor, which confirms its continued usage in candy confections.

For the Australian varieties, Rhea was the highest ranking in market potential, taste, aroma/flavor, and hedonic sum. The Spanish and Israeli varietals have qualities distinct from the current U.S. industry standards.

Based on the value of the sensory data collected at the Crack-Out event, the Almond Board will support additional compositional analyses on a number of the varieties that scored highly at the event. Preliminary compositional analyses are presented on Table 3-A of the appendix report.

Conclusions

The data collected during the 2019 Crack-Out event indicate that varieties/selections within the RVTs, and U.S. and international breeding programs, offer a wide diversity of value across the various sectors of the almond industry.

Table IV-I below provides a summary of the key tree characteristics, kernel quality characteristics, and sensory characteristics for varieties and selections that are part of the current RVTs. **More years of yield data collection are needed to confirm these preliminary results.** So far, there are several candidate varieties/selections that are presenting high yield efficiency and additional benefits such as self-compatibility and desired sensory attributes. These results are encouraging.

For those in the RVTs, the selections and varieties that met the following three requirements were included in this table:

1. produced an average of more than 30 lbs. of kernels (yield) per percentage of photosynthetic active radiation (PAR) intercepted in 2018 and 2019 across counties,
2. had doubles equal to or less than 10%,
3. had a crack-out percent equal to or higher than 40%.

Selections/varieties that met the yield/PAR criteria but did not meet both the doubles and crack-out criteria were eliminated from the table (UCD 18-20, UCD 8-201, Y121-42-99, Booth). Self-compatible varieties or selections are preferred over non-self-compatible varieties. Varieties or selections with a hedonic score equal to or higher than 30 points are also preferred. Note that several of the varieties in this table are presenting a very “weepy” growing habit. While this “weepy” habit has not been a problem to date, more years of data collection are needed to clarify this situation.

Table IV-I. Overall summary of key tree, kernel quality, and sensory characteristics for varieties and selections that are part of the current RVTs. **Only RVT selections and varieties that met the following three requirements were included in this table: i) Produced an average of more than 30 lbs. of kernels (yield) per percentage of photosynthetic active radiation (PAR) intercepted in 2018 and 2019 across counties; ii) Had doubles equal to or less than 10%; iii) Had a crack-out % equal to or higher than 40%.** FBD = Full Bloom Date. NP = Nonpareil. Selections/varieties that met the yield/PAR criteria but did not meet both the doubles and crack-out criteria were eliminated from the table (UCD 18-20, UCD 8-201, Y121-42-99, Booth). Self-compatible varieties or selections are preferred over non-self-compatible varieties. Varieties or selections with a hedonic score equal to or higher than 30 points are also preferred. Note that several of the varieties in this table are presenting a very "weepy" growing habit. While this "weepy" habit has not been a problem to date, more years of data collection are needed to clarify this situation. **Varieties or selections are listed in alphabetical order and their relative order in the table does not represent any technical ranking.**

Tree Characteristics			Kernel quality characteristics		Sensory characteristics
Var. or selection	**Self-compatible?**	**FBD +/- NP days**	**Crack-out Percent**	**Doubles Percent**	**Hedonic score >30 points**
Aldrich	No	+0	60	7	Yes
Bennett	No	+0	68	3	Yes
Durango	No	+0	58	6	Yes
Jenette	No	+1	67	6	No
Kester	No	+5	56	3	No
Kester/Hansen*	No	+7	78	3	No
Nonpareil	No	+0	67	5	N.A.
Self-fru P13.019	Yes	+3	43	6	No
UCD 1-16	No	-1	62	10	Yes
UCD 7-159	Yes	-1	70	1	Yes
UCD 8-160	Yes	+0	60	6	Yes
Winters	Partial	+0	56	4	No
Wood Colony	No	+1	64	10	No
Y116-161-99	Yes	+0	67	2	Yes
Y117-86-03	Yes	+3	70	3	Yes
Y117-91-03	Yes	+3	70	3	Yes

*The crack-out % difference between Kester and Kester/Hansen requires further data exploration.

Table V-II below lists the new varieties or selections that are not part of the current RVTs and meet the following criteria: (i) Self-compatible; (ii) Have a crack-out equal or higher than 40%; (iii) Doubles equal or lower than 10%. These non-RVT varieties or selections could be formally evaluated for their hedonic characteristics and then included in a new set of RVTs to record their yield/general horticultural performance in California. New selections or varieties that might be developed in the future, or that are not part of this report, could follow the recommended stepwise evaluation process outlined above.

Table IV-II. Varieties or selections not part of the current RVTs and whose performance may be further evaluated as they already meet the following screening: (i) Self-compatible; (ii) Have a crack-out percent higher than 40%; (iii) Doubles equal or lower than 10%.

Variety	Source
Shasta	Burchell, CA
Pyrenees	Burchell, CA
Vela	Adelaide, Australia
Selection D06-795	CEBAS CSIC, Spain
Selection D01-188	CEBAS CSIC, Spain
Matan	Volcani Center, Israel
Mira	Adelaide, Australia
Independence	Zaiger Genetics, CA
5ZR754	Zaiger Genetics, CA

Priority Traits for New Variety Development

The versatility of California almonds enables their use in diverse market segments. Retaining that versatility as the industry shifts toward self-compatible varieties is thus valued. Self-compatible varieties are strongly preferred for the likely lower cost of pollination and more uniform horticultural management. Table IV-III summarizes priority traits based on ABC consultations. Those traits listed as “breed for” targets are those that are offer significant value over current varieties. Those listed as “screen for” targets represent important traits preferred by the California industry. Together, the two lists represent priorities for future variety development.

Table IV-III. List of desired almond variety traits that ABC has prioritized as desirable to breed for in genetic improvement programs and screen for in variety evaluation programs.

Breed for	Screen for

• Self-fruitful
• High and consistent yield across years (above 3,500 lbs./acre): High productivity per area of productive wood. Lack of alternate bearing. Balanced growth habit between fruiting and non-fruiting spurs.
• Easy to shake
• Harvest date earlier than Nonpareil variety or around two weeks after Nonpareil variety
• Flavor and quality development:
  ○ Improved oil content in the 50%range or enhanced Alpha-Tocopherol (over 20 mg/100g)
  ○ High protein (over 20%)
	• Bloom time: No earlier than Nonpareil variety
	• Compacted and consistent bloom duration
	• Intense bloom
	• Medium vigor
	• Branching habit: self-supporting, minimal need for pruning or major training
	• Free of, or insignificant expression of, bud failure
	• Compatibility with multiple rootstocks
	• Shell: Paper and soft shell with closed suture
	• Crack-out equal to or higher than 40%
	• Kernel:
	  ○ Light or blond color skin
	  ○ Medium to large size
	  ○ Flat shape
	  ○ Smooth surface
	  ○ Fewer than 10% doubles
	  ○ Fewer than 1% twin kernels
	  ○ Free of "other defects" such as gum, shrivel, brown spot, and discolorations
	  ○ Uniform shape and thickness
	• Shaking no later than Sept. 15
	• Hull: Butterfly opening that allows easy hulling, and maximizes natural kernel drying
	• More disease and pest resistance than the Nonpareil variety
	• Easy to blanch
	• Reduced free asparagine levels

We also see niche market opportunities across our industry for additional traits that have value for specific segments or uses:

- Kernels to satisfy the needs of the candy and chocolate industry

    - Short, small, and plump kernels
    - Smooth to wrinkled kernel surfaces
- Unique kernel sizes and shapes, strong flavor, or high protein content
    - Unique physical, chemical and sensory properties
    - Kernels with light to brown color, and smooth skin surface
    - Roasting characteristics superior to the Carmel variety
    - Light-to-dark brown kernel color

Future Directions

In addition, based on the consultations leading up to and from this analysis, ABC will work with researchers, breeders and nurseries to improve the value of investments in new variety development and evaluation. This includes establishing criteria for inclusion in RVTs and integrating sensory evaluation into the screening process as follows:

Step 1. Call for varieties or selections that meet the following minimal criteria: (Note: ABC's sponsored public breeding program will use the interim-evaluation plots for this step)**:**

- Bloom time no earlier than Nonpareil
- Self-compatible
- Crack-out percent equal to or higher than 40%
- Percentage of double kernels equal to or lower than 10%

Step 2. Sensory screening (sensory panel)

- A hedonic score >30 was used in this report based on the data collected in the 2019 Crack-Out event. In the future, a formal sensory panel evaluation should be part of this process.

Step 3. Evaluating the production/horticultural performance of final selections/varieties. (This should not be a screening step, but a performance test at RVTs.)

- Step 3-I: Yield/PAR >30 when combining year four and five of orchard production.
- Step 3-II: Track best candidates for overall assessment for a total of 15 years.

Appendix

ABC Active Breeding Projects as of 2019-20 Fiscal Year

Table Appendix-1 provides a list of active breeding projects as of the 2019-20 fiscal year.

Table A-1. List of active research projects funded by ABC in 2019-20 fiscal year as part of the breeding and evaluation of almond variety portfolio (n = 14; Total investment 19-20 fiscal year = $816,043).

Institution	Principal Investigator	Project Title
USDA	John E. Preece	Support for the National Clonal Germplasm Repository
UC Davis	Brian Bailey	Three-dimensional model-based analysis of the impact of variability in almond tree structure and configuration
UC Davis and UC ANR	Bruce Lampinen and Phoebe Gordon	Field evaluation of almond varieties
UC Davis	Bruce Lampinen	New germplasm and training systems for high density catch frame almond systems
		Utilizing canopy light interception/yield data to improve management of almond
UC Davis	Tom Gradziel	Almond variety development
		Accelerated assessment of almond variety candidates
UC Davis	Gina Sideli	The application of molecular tools and quantitative phenotyping for genomics-assisted breeding in almond
UC Davis	Alyson Mitchell	Chemical characterization of new almond varieties
UC ANR	Roger Duncan	Integration of tree spacing, pruning, and rootstock selection for efficient almond production
Spain-CEBAS-CSIC	Pedro Jose Martinez-Garcia	Discovery of genetic variation in related self-fertile species of almond
Plant and Research AUS	Grant Thorp	Tree architecture and development of new growing system
Ohio State University	Jonathan Fresnedo-Ramirez	Gene prediction and genome annotation of Nonpareil
		Applied epigenomics towards measuring the risk of noninfectious bud failure in almond

Material, Methods and Additional Crack-Out Results

Nut samples of the almond varieties were shipped domestically and internationally to UC Davis and stored at the UC Davis postharvest facility in plastic bags at 32°F (0°C). In-shell samples from the north hemisphere were two months old, whereas the in-shell samples from the south hemisphere were at least six months old, which could have a significant impact on the flavor and texture scoring. This results in 64 samples that were cracked at the Pomology Field Facility in Davis. Ten average nuts per variety were measured and the mean values for kernel length, width and thickness were determined for each variety. Shelled almonds were also qualitatively scored for pellicle color and kernel texture. Shell thickness was measured with a caliper.

Two days prior to the Crack-Out event, three kernels of each variety/selection were placed into multiple sealed plastic cups for blind tasting and stored at room temperature. Participation in the almond tasting panel was completely voluntary and was carried out at the Double Tree Hotel in Modesto CA on November 13, 2019. Attendees were divided into three groups, with each group consisting of 14 to 19 individuals.

Individuals first sampled the Nonpareil variety as a standard, then blindly sampled 20 varieties. Attendees were provided with a checklist for sample tracking and rotated themselves around a group of tables to sample each variety. At each station, an envelope was provided with a hedonic ranking scale for each variety along with a cup of three kernels of individual varieties to sample. Attendees were given cucumber water to cleanse palette between sampling each variety.

The genotypes represented included samples collected from ABC-funded RVTs, samples sent from Spanish, Australian and Israeli breeding programs, as well as some private Californian breeding programs (Table III-1). Six selections were only brought to the Crack-Out event and so we did not have the opportunity to do kernel quality evaluations mentioned above.

Table A-2. Domestic and international varieties/selections presented at the Crack-Out event (n = 70). RVT = Regional variety trials (Butte, Madera, Stanislaus counties in California). IRTA = Institute of Agrifood Research and Technology. Lleida, Spain. CITA = Aragon Agrifood Research and Technology Center. Zaragoza, Spain. CEBAS-CSIC = Centro de Edafologia Biologia Aplicada del Segura - Consejo Superior De Investigaciones Cientificas, Murcia, Spain. Volcani Center = Agricultural Research Organization, Rishon LeZion, Israel.

Cultivar	Self-fertile	Country	Classification	RVT	Source
Aldrich	no	U.S.	variety	present	Fowler
Bennett	no	U.S.	variety	present	Duarte
Booth	no	U.S.	variety	present	Burchell
Butte	no	U.S.	variety		
Capitola	no	U.S.	variety	present	Burchell
Carmel	no	U.S.	variety		Burchell
Durango	no	U.S.	variety	present	Fowler
Eddie	no	U.S.	variety	present	Bright's
Folsom	no	U.S.	variety	present	Wilson
Independence	yes	U.S.	variety		Zaiger
Jenette	no	U.S.	variety	present	Fowler
Kester (2-19E)	no	U.S.	variety	present	UC Davis
Mission	no	U.S.	variety		
Monterey	no	U.S.	variety		Burchell
Nonpareil	no	U.S.	variety	present	Fowler
Peerless	no	U.S.	variety		
Pyrenees	yes	U.S.	variety		Burchell
Self-fru P13.019	yes	U.S.	selection	present	Burchell
Self-fru P16.013	yes	U.S.	selection	present	Burchell
Shasta	yes	U.S.	variety		Burchell
Sonora	no	U.S.	variety		UC Davis
Sterling	no	U.S.	variety	present	Burchell
Supareil	no	U.S.	variety	present	Burchell
Sweetheart	partial	U.S.	variety	present	UC Davis
5ZR754	yes	U.S.	variety		Zaiger
UCD 1-16	no	U.S.	selection	present	UC Davis

Cultivar	Self-fertile	Country	Classification	RVT	Source
UCD 1-232	yes	U.S.	selection	present	UC Davis
UCD 1-271	yes	U.S.	selection	present	UC Davis
UCD 3-40	no	U.S.	selection	present	UC Davis
UCD 7-159	yes	U.S.	selection	present	UC Davis
UCD 8-27	yes	U.S.	selection	present	UC Davis
UCD 8-160	yes	U.S.	selection	present	UC Davis
UCD 8-201	yes	U.S.	selection	present	UC Davis
UCD 10, 2-2	yes	U.S.	selection		UC Davis
UCD 10, 3-25	yes	U.S.	selection		UC Davis
UCD 10, 5-292	yes	U.S.	selection		UC Davis
UCD 10C-1-16	yes	U.S.	selection		UC Davis
UCD 18-20	no	U.S.	selection	present	UC Davis
UCD 98, 2-305	yes	U.S.	selection		UC Davis
Winters	partial	U.S.	variety	present	UC Davis
Wood Colony	no	U.S.	variety	present	Burchell
Y116-161-99	yes	U.S.	selection	present	USDA
Y117-86-03	yes	U.S.	selection	present	USDA
Y117-91-03	yes	U.S.	selection	present	USDA
Y121-42-99	yes	U.S.	selection	present	USDA
Capella	yes	Australia	variety		University of Adelaide
Carina	yes	Australia	variety		University of Adelaide
Maxima	no	Australia	variety		University of Adelaide
Mira	yes	Australia	variety		University of Adelaide
Rhea	no	Australia	variety		University of Adelaide
Vela	yes	Australia	variety		University of Adelaide
Constanti	yes	Spain	variety		IRTA

Cultivar	Self-fertile	Country	Classification	RVT	Source
Marinada	yes	Spain	variety		IRTA
Tarraco	no	Spain	variety		IRTA
Vairo	yes	Spain	variety		IRTA
Selection Ô29-148Õ	yes	Spain	selection		IRTA
Selection Ô30-297Õ	yes	Spain	selection		IRTA
Belona	yes	Spain	variety		CITA
Guara	yes	Spain	variety		CITA
Mardia	yes	Spain	variety		CITA
Soleta	yes	Spain	variety		CITA
Vialfas	yes	Spain	variety		CITA
Antoneta	yes	Spain	variety		CEBAS-CSIC
Makako	yes	Spain	variety		CEBAS-CSIC
Marta	yes	Spain	variety		CEBAS-CSIC
Penta	yes	Spain	variety		CEBAS-CSIC
Selection 'D00-360'	yes	Spain	selection		CEBAS-CSIC
Selection 'D01-188'	yes	Spain	selection		CEBAS-CSIC
Selection 'D06-795'	yes	Spain	selection		CEBAS-CSIC
Matan	yes	Israel	variety		Volcani Center

Eleven samples with high hedonic scores or unique properties were selected from the Crack-Out event in November 2019, and were analyzed by a USDA certified food analysis laboratory, a subsidiary of Eurofins (USDA certified lab for food analysis, Madison, WI) for full nutrient composition including proximate analysis (moisture, protein, fat and ash), sugars, dietary fibers, fatty acids, phytosterols, tocopherols, amino acids, and elements. All data are summarized in the following table. All the samples show a comparable level in macro nutrients (protein, fat, sugars, dietary fibers). The sample of Y117-91-03 and Matan show some variation or unique composition compared to other varieties or selections. Most samples show a comparable level in tocopherols and phytosterols except for Matan. Y117-91-03 shows a higher level of protein and lower level of fat while Matan contain much higher level of monounsaturated fatty acids, and lower levels in polyunsaturated fatty acids, phytosterols, and tocopherols. **This data was collected from a single sample of each variety or selection, and thus it is only indicative. Definitive conclusions must rely on analysis of more samples.**

Table A-3. Nutrient composition of selected samples from one sample per variety.

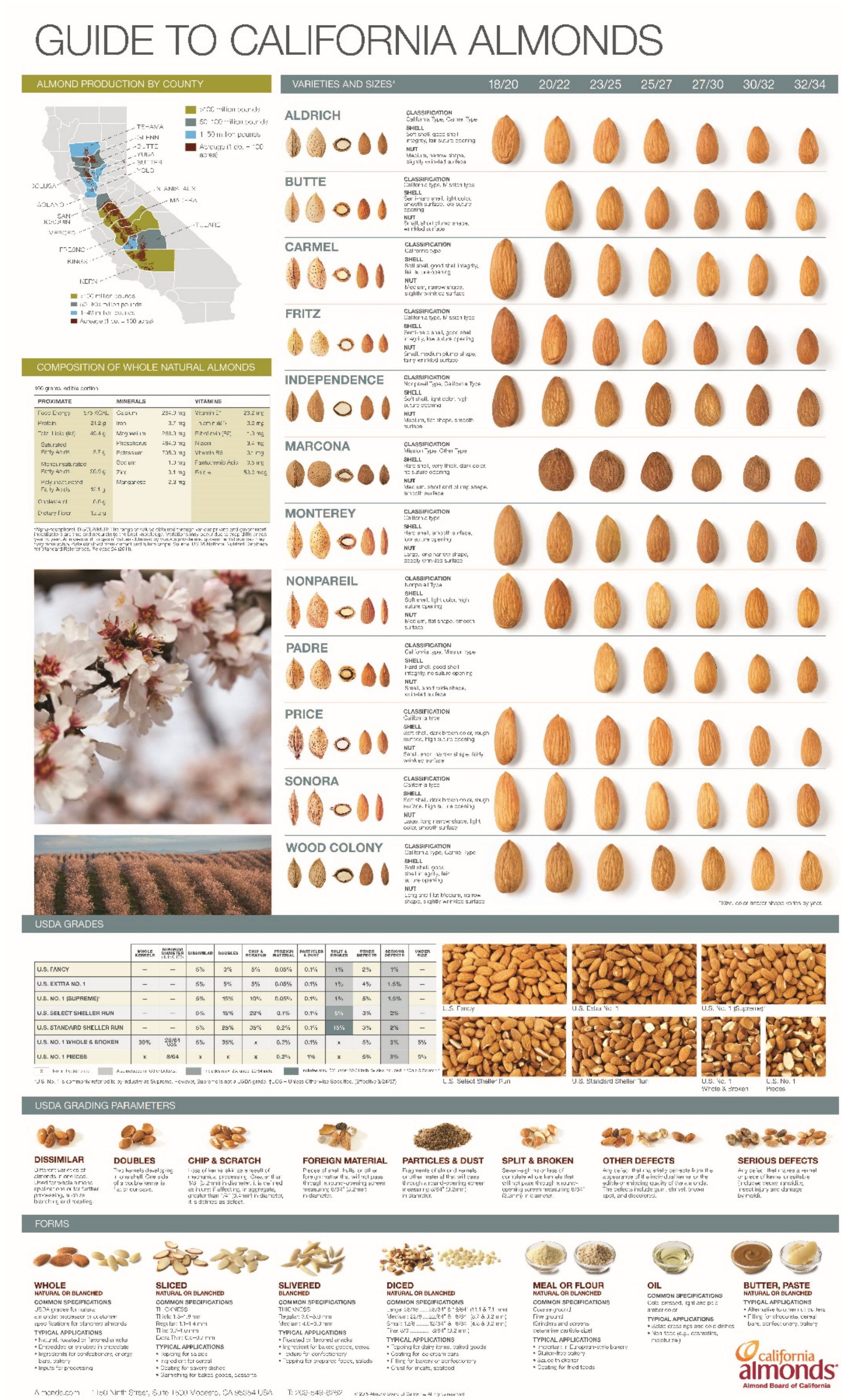
Nutrient Composition of Selected Samples from Crack-out Event												
Nutrient	**UOM**	**Bennett**	**Eddie**	**Matan**	**Mira**	**Pyrenees**	**Supareil**	**UCD 1-271**	**UCD 8-160**	**Y116-161-99**	**Y117-86-03**	**Y117-91-03**
Proximate												
Moisture	g/100g	3.84	4.46	5.44	4.85	3.81	3.99	3.36	3.53	3.79	3.97	3.61
Protein	g/100g	20	21.6	21.5	19.1	21.3	19.5	22.6	19.2	20.6	22.2	25.8
Fat	%	49.9	46.1	49.3	51.2	51.8	50.8	51.9	52.6	51.5	49.2	44.3
Ash	g/100g	3.01	3.09	3.31	2.86	2.92	3.06	2.91	3.26	2.96	3.36	3.03
Sugars												
Total Sugar	g/100g	4.8	4.9	4.1	4.4	3.9	4.6	2.7	4.4	4.2	3.7	3.6
Fructose	g/100g	<0.1	<0.1	0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Glucose	g/100g	<0.1	<0.1	0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Sucrose	g/100g	4.8	4.9	3.8	4.1	3.9	4.6	2.7	4.4	4.2	3.7	3.6

Dietary Fibers												
Total Dietary Fiber	g/100g	13.7	13.1	11.7	12.5	11.2	12.9	11.3	11.8	11.6	12.5	12.2
Soluble Fiber	g/100g	1.02	1.28	1.35	1.27	1.28	1.29	1.02	1.4	1.12	1.28	1.16
Insoluble Fiber	g/100g	12.7	11.8	10.3	11.2	9.92	11.6	10.3	10.4	10.5	11.2	11
Fatty Acids												
Total Fatty Acids	g/100g	49.1	45.1	48.6	50.2	51	49.9	51.4	51.8	50.8	48.3	43.5
Monounsaturated Fatty Acids	g/100g	33.2	28.4	38	29.5	35.7	32.9	32	33.5	32.8	31.3	28.6
16:1 Palmitoleic	g/100g	0.26	0.22	0.17	0.28	0.2	0.24	0.18	0.22	0.14	0.14	0.18
9c 18:1 Oleic	g/100g	33.7	28.8	38.9	29.8	36.5	33.3	32.7	34.1	33.6	32.1	29.2
Total 18:1 cis	g/100g	34.4	29.4	39.5	30.6	37.1	34.1	33.2	34.7	34.1	32.5	29.6
Polyunsaturated Fatty Acids	g/100g	10	11	5.26	14.1	9.12	11.2	12.6	12.1	11.6	10.9	9.54
18:2 Linoleic	g/100g	10.5	11.5	5.49	14.7	9.53	11.7	13.2	12.7	12.1	11.4	9.97
Omega 6 Fatty Acids	g/100g	10.5	11.5	5.49	14.7	9.53	11.7	13.2	12.7	12.1	11.4	9.97
Omega 9 Fatty Acids	g/100g	33.7	28.8	38.9	29.8	36.5	33.3	32.7	34.1	33.6	32.1	29.2
Total Cis Unsaturated Fatty Acids	g/100g	43.2	39.4	43.3	43.6	44.8	44.1	44.6	45.6	44.4	42.2	38.1
Saturated Fatty Acids	g/100g	3.69	3.7	3.23	4.38	3.97	3.65	4.53	3.97	4.22	4.05	3.53
16:0 Palmitic	g/100g	3.27	3.35	2.81	3.86	3.11	3.28	3.83	3.37	3.44	3.04	2.92
18:0 Stearic	g/100g	0.57	0.53	0.57	0.7	1	0.55	0.88	0.71	0.94	1.16	0.74

Phytosterols												
Total Sterols	mg/100g	143	155	124	161	200	149	158	156	158	162	167
Beta Sitosterol	mg/100g	114	123	102	126	170	117	117	129	122	130	133
Campesterol	mg/100g	5.12	5.15	4.33	4.64	3.93	5.28	4.47	4.46	4.02	4.12	4.38
Stigmasterol	mg/100g	3.91	4.98	1.73	3.02	1.48	6.38	1.12	2.23	3.26	1.15	4.75
Other Sterols/Stanols	mg/100g	19.9	21.7	16.2	27.5	24.8	20.9	35.4	20.2	28.6	26.9	24.8
Tocopherols												
Total Tocopherols	mg/100g	28.1	28.6	20.3	35.4	25	27.4	26.9	31.3	30.9	28.9	29.4
Alpha Tocopherol	mg/100g	27	27.6	19.5	34	24	26.6	25.3	29.8	29.1	27.6	28.3
Beta Tocopherol	mg/100g	0.28	0.23	0.2	0.36	0.21	0.26	0.21	0.21	0.31	0.25	0.19
Gamma Tocopherol	mg/100g	0.85	0.76	0.62	1.04	0.82	0.52	1.44	1.24	1.46	1.05	0.87
Amino Acids												
Alanine	g/100g	1.01	1.11	1.1	0.96	1.09	0.99	1.15	0.97	1.1	1.17	1.29
Arginine	g/100g	2.35	2.57	2.68	2.22	2.54	2.37	2.62	2.26	2.55	2.63	3.12
Aspartic Acid	g/100g	2.35	2.65	2.45	2.19	2.51	2.31	2.72	2.19	2.57	2.71	3.04
Cystine	g/100g	0.28	0.29	0.31	0.28	0.29	0.27	0.27	0.28	0.26	0.29	0.35
Glutamic Acid	g/100g	5.53	6.02	6.43	5.4	6.08	5.6	6.03	5.52	5.95	6.15	7.16
Glycine	g/100g	1.4	1.43	1.45	1.48	1.48	1.47	1.48	1.4	1.39	1.4	1.58
Histidine	g/100g	0.49	0.53	0.54	0.49	0.53	0.49	0.53	0.49	0.51	0.52	0.61
Isoleucine	g/100g	0.86	0.93	0.95	0.83	0.92	0.85	0.98	0.82	0.94	0.98	1.09
Leucine	g/100g	1.48	1.66	1.63	1.44	1.68	1.48	1.78	1.42	1.73	1.75	1.95
Lysine	g/100g	0.65	0.64	0.65	0.66	0.6	0.65	0.6	0.64	0.62	0.61	0.67

Amino Acids												
Methionine	g/100g	0.22	0.21	0.2	0.2	0.22	0.21	0.2	0.21	0.21	0.21	0.23
Phenylalanine	g/100g	1.16	1.26	1.34	1.15	1.26	1.15	1.28	1.12	1.28	1.31	1.49
Proline	g/100g	0.93	1.02	0.97	0.89	1	0.91	1.09	0.88	1.04	1.05	1.19
Serine	g/100g	0.87	0.96	0.94	0.86	0.98	0.88	1.04	0.86	0.99	1.01	1.14
Threonine	g/100g	0.65	0.69	0.68	0.64	0.68	0.65	0.74	0.61	0.7	0.72	0.79
Tyrosine	g/100g	0.7	0.78	0.75	0.67	0.78	0.7	0.83	0.67	0.79	0.81	0.91
Valine	g/100g	0.96	1.07	1.03	0.93	1.05	0.93	1.13	0.89	1.08	1.11	1.25
Tryptophan	g/100g	0.2	0.23	0.2	0.16	0.2	0.17	0.2	0.17	0.2	0.24	0.27
Elements												
Calcium	mg/100g	288	294	314	273	295	270	270	265	299	380	334
Copper	mg/100g	0.9	1.19	1.28	0.67	0.79	0.98	0.91	1.01	1.14	1.23	1.01
Iron	mg/100g	4.79	5.18	3.9	3.67	4.06	3.33	7.15	5.74	4.09	7.18	7.26
Magnesium	mg/100g	282	303	260	265	252	293	264	286	257	299	276
Manganese	mg/100g	1.84	2.4	2.4	4.44	2.02	2.28	2.24	1.85	1.8	1.98	2.09
Phosphorus	mg/100g	472	494	620	475	522	489	507	544	487	532	504
Potassium	mg/100g	658	699	813	766	660	730	599	756	651	696	647
Sodium	mg/100g	<3.96	<3.98	<3.86	<3.95	<3.99	<3.92	<3.89	<3.92	<3.94	<4.00	<3.98
Zinc	mg/100g	2.17	2.66	3.77	3.28	2.67	2.31	2.38	2.46	2.63	2.89	2.48

ABC Almond Classification - Variety Poster



STANDARDS & GRADES

USDA grades for natural almonds are voluntary minimum standards. The California Almond industry can supply almonds to customers' unique specifications, both in terms of sizes and grades, based on the intended applications.

USDA grades establish tolerances for various quality factors. Depending on the ultimate use, different grades may be more relevant than others. Other terms like "Supreme" are also used in the industry when referring to particular grades. Be sure to speak with your supplier about your specifications.

1 U.S. ton = 0.907 metric ton
1 metric ton = 2,204.6 pounds
1 pound = 453.6 grams
10 oz. = 283.5 grams

USDA GRADES OF SHELLED ALMONDS

USDA GRADES	WHOLE KERNELS	MINIMUM DIAMETER (IN INCHES)	DISSIMILAR	DOUBLES	CHIP & SCRATCH	FOREIGN MATERIAL	PARTICLES & DUST	SPLIT & BROKEN	OTHER DEFECTS	SERIOUS DEFECTS	UNDER SIZE
U.S. FANCY	—	—	5%	3%	5%	0.05%	0.1%	1%	2%	1%	—
U.S. EXTRA NO. 1	—	—	5%	5%	5%	0.05%	0.1%	1%	4%	1.5%	—
U.S. NO. 1 (SUPREME)*	—	—	5%	15%	10%	0.05%	0.1%	1%	5%	1.5%	—
U.S. SELECT SHELLER RUN	—	—	5%	15%	20%	0.1%	0.1%	5%	3%	2%	—
U.S. STANDARD SHELLER RUN	—	—	5%	25%	35%	0.2%	0.1%	15%	3%	2%	—
U.S. NO. 1 WHOLE & BROKEN	30%	20/64 UOS†	5%	35%	x	0.2%	0.1%	x	5%	3%	5%
U.S. NO. 1 PIECES	x	8/64	x	x	x	0.2%	1%	x	5%	3%	5%

*U.S. No. 1 is commonly referred to by industry as Supreme. However, Supreme is not a USDA grade.
†UOS = Unless Otherwise Specified.

No limit established. x
Also included in "Other Defects."
Includes max. 2% under 20/64 inch.
Includes max. 5% under 20/64 inch. % also included in "Chip & Scratch."

CALCULATION OF GRADING PERCENTAGES (EXAMPLE)

$$\% \text{ [DISSIMILAR KERNELS]} = \frac{\text{WEIGHT OF [DISSIMILAR KERNELS] (G) X 100}}{\text{WEIGHT OF TOTAL SAMPLE (G)}}$$

UNDERSTANDING USDA GRADES

The different grades are defined by the allowable minimum standards/tolerances for each grade of almonds. The higher the percentage listed on the chart, the higher the tolerance for that particular grade factor.

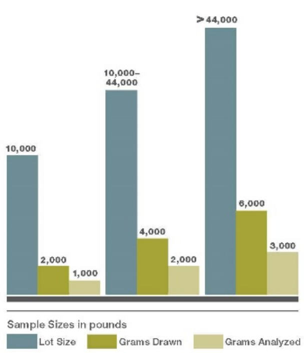
Almonds are a natural product, so there can be variations within grades and among shipments. For example, while U.S. Fancy cannot have more than 5% dissimilar almonds, depending upon the conditions of that crop year, the actual percentage in the shipment could range from 0 to 5%.

USDA GRADES OF IN-SHELL ALMONDS

USDA GRADES	MEDIUM	EXTERNAL DEFECT	DISSIMILAR	UNDER SIZE	FOREIGN MATERIAL	INTERNAL (KERNEL) DEFECT
U.S. NO. 1*	28/64	10%	5%	5%	2%	10%
U.S. NO. 1 MIXED	28/64	10%	—	5%	2%	10%
U.S. NO. 2	28/64	10%	5%	5%	2%	10%
U.S. NO. 2 MIXED	28/64	10%	—	5%	2%	10%

*U.S. No. 1 is commonly referred to by industry as Supreme. However, Supreme is not a USDA grade.

Includes max. 5% serious, no live insects in shell.
Includes max. 1% less than 24/64 by weight. All others by count.
Additional 20% for discoloration of shell.



UNDERSTANDING USDA SHELLED GRADES

More rigorous specifications are typically negotiable to meet customer's application requirements.

U.S. FANCY
The highest grade—typically appropriate for products where the visual appeal of the almond is critical to the application.

U.S. EXTRA NO. 1
Similar to U.S. Fancy—ideal for food applications where the appearance of the almond is very important.

U.S. NO. 1
Sometimes referred to as Supreme, and often used for whole almond applications or for further processing like blanching and roasting.

U.S. SELECT SHELLER RUN
Mid-quality grade—good choice for applications where the almonds with minimal sorting/processing can be incorporated with other ingredients; for example, inside a confectionery product a higher level of chipped and scratched kernels is accepted. Also appropriate for further processing, such as blanching, grinding, roasting, dicing and slicing.

U.S. STANDARD SHELLER RUN
Good grade for further processing, such as blanching, dicing, grinding or paste, particularly where a higher level of split and broken kernels is not a concern.

USDA GRADING PARAMETERS

The following is the breakdown of parameters that affect the grading for almonds, regardless of the variety or size.

DISSIMILAR
Different varieties of almonds in one load. Used for whole almond applications or for further processing, such as blanching and roasting.

DOUBLES
Two kernels developing in one shell. One side of a double kernel is flat or concave.

CHIP & SCRATCH
Loss of kernel skin as a result of mechanical processing. Greater than 1/8" (3.2mm) in diameter, is defined as injury; if affecting, in aggregate, greater than 1/4" (6.4mm) in diameter, it is defined as defect.

FOREIGN MATERIAL
Pieces of shell, hulls or other foreign matter that will not pass through a round-opening screen measuring 8/64" (3.2mm) in diameter.

PARTICLES & DUST
Fragments of almond kernels or other material that will pass through a round-opening screen measuring 8/64" (3.2mm) in diameter.

SPLIT & BROKEN
Seven-eighths or less of complete whole kernels that will not pass through a round-opening screen measuring 8/64" (3.2mm) in diameter.

OTHER DEFECTS
Any defect that materially detracts from the appearance of the individual kernel or the edible or shipping quality of the almonds The defects include gum, shrivel, brown spot and discolored.

SERIOUS DEFECTS
Any defect that makes a kernel or piece of kernel unsuitable (includes decay, rancidity, insect injury and damage by mold).

UNDERSTANDING USDA IN SHELL GRADES

U.S. NO. 1
Similar varietal characteristics. Free from loose, extraneous and foreign material.

Shells are clean, fairly bright, fairly uniform in color and free from damage caused by discoloration, adhering hulls, broken shells or other means. Kernels are well dried, free from decay, rancidity, damage caused by insects, mold, gum, skin discoloration, shriveling, brown spots or other means.

LOOSE FOREIGN MATERIAL
2%, including 1% passing through a 24/64" screen (this is also by weight).

INTERNAL DEFECTS
10%, including 5% serious damage.

U.S. NO. 1 MIXED
U.S. No. 1 grade, except that two or more varieties are mixed.

U.S. NO. 2
Consists of almonds in the shell that meet the requirements of U.S. No. 1 grade, except that an additional tolerance of 20% shall be allowed for almonds with shells damaged by discoloration.

U.S. NO. 2 MIXED
Consists of almonds in the shell that meet the requirements of U.S. No. 2 grade, except that two or more varieties of almonds are mixed.

SIZE
Unless otherwise specified, 28/64" in thickness.

Almonds.com

california almonds
Almond Board of California

Index