Almond Variety Development

Project No.: **17-HORT1-Gradziel**

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Objectives:

Develop improved pollinizers for *Nonpareil*, as well as varieties that possess self-fertility and improved market value and resistance to disease, insects and environmental stress. Specific objectives for 2015-16 include:

1. Generate 12,000 new seedling progeny with subsequent field plantings of ~6,000 new trees. Evaluate and reduce by an additional 5% the ~12,000 progeny trees currently in breeding trials through continued development and implementation of low-input/high-throughput breeding efficiency strategies.
2. Identify effective predictors of yield potential (annual and cumulative) to assess opportunities/limitations of traditional as well as evolving biotech approaches including molecular marker-assisted-selection (MAS).
3. Assess opportunities and limitations of advance breeding germplasm currently being tested in Regional Variety Trials (RVTs). Expand smaller regional grower new trials to evaluate next generation selections.

Interpretive Summary

The California almond industry is in a period of historic transformation driven by increasing environmental and market demands, reductions in water and other natural resources, loss of natural pollinators and changing climate. While almond represents a diverse and highly adaptable species, commercial production is dependent almost entirely on the variety Nonpareil and its pollinizers, most of which have Nonpareil and Mission as direct parents. Consequently, the UCD Almond Variety Development program has worked to incorporate promising new and diverse germplasm to provide new genetic solutions to traditional as well as emerging production challenges. The recent release of *Kester* as a very productive, high kernel-quality pollinizer for later *Nonpareil* bloom, and *Sweetheart* as a premium quality, Marcona-type almond possessing partial self-compatibility, very high levels of the heart-healthy phytonutrient oleic-acid, as well as improved resistance to navel orangeworm and aflatoxin contamination, demonstrates the potential of this germplasm. Selections now in regional testing combine good productivity and market quality with self-fruitfulness and improved resistance to diseases, pests and environmental stresses. The next generation of breeding crosses target further refinement of these desirable characteristics while incorporating additional new germplasm and so potentially new genetic solutions to California production and market problems.

<u>New Crosses</u>
Over 26,000 crosses were made in 2017 with a slightly lower number accomplished in 2018. Weather conditions made both crossing and hybrid seed recovery difficult with frequent rains being a challenge in 2017 while frost-damage represented the greatest challenge in 2018. Over 10,000 breeding seed were harvested 2017 with a somewhat lower number anticipated in 2018. Recovered seed represent both advanced, high quality and regionally adapted almonds possessing novel genes for self-fruitfulness and improved disease/pest/environmental stress resistance. Approximately 5,000 seed from 2017 crosses have been transplanted to the field evaluation plots with a similar number of seedlings currently being evaluated in UCD greenhouses.

<u>Advanced Selections.</u>
Promising UCD breeding selections have been advanced to regional grower trials including the new Regional Variety Trials (RVT) located in Butte, Stanislaus and Madera counties. Selections combine good market quality and regional adaptability with novel traits for improved orchard productivity. Novel traits include self-fruitfulness, drought-stress, improved disease and pest resistance, and modified tree architectures and bearing habits to augment current and emerging crop management strategies.

<u>Yield assessments</u>.
UCD breeding selections are among the top yielders in early RVT results while retaining a diversity of growth and development patterns. The evaluation of yield potential is evolving from a more simplistic measurement of tree production under high nutrient and water inputs to an assessment of whole orchard performance including conditions were inputs such as nitrogen or water become limiting.

Materials and Methods:

The objective of the UCD Almond Variety Development Program is to develop improved pollinizers for *Nonpareil*, and, ultimately replacements for Nonpareil that possess self-fruitfulness and enhanced market value and improved resistance to disease, insects and environmental stress. The variety Nonpareil has dominated California production for over 100 years based on its high productivity and adaptability to a range of different environments (see following Regional Variety Trial [RVT] summaries) as well as its well-established market value. An analysis of production and market trends over the last 20 years documents a stabilizing trend for Nonpareil planting at roughly 40% as well as a consistently superior market value over other varieties (**Figure 1**).

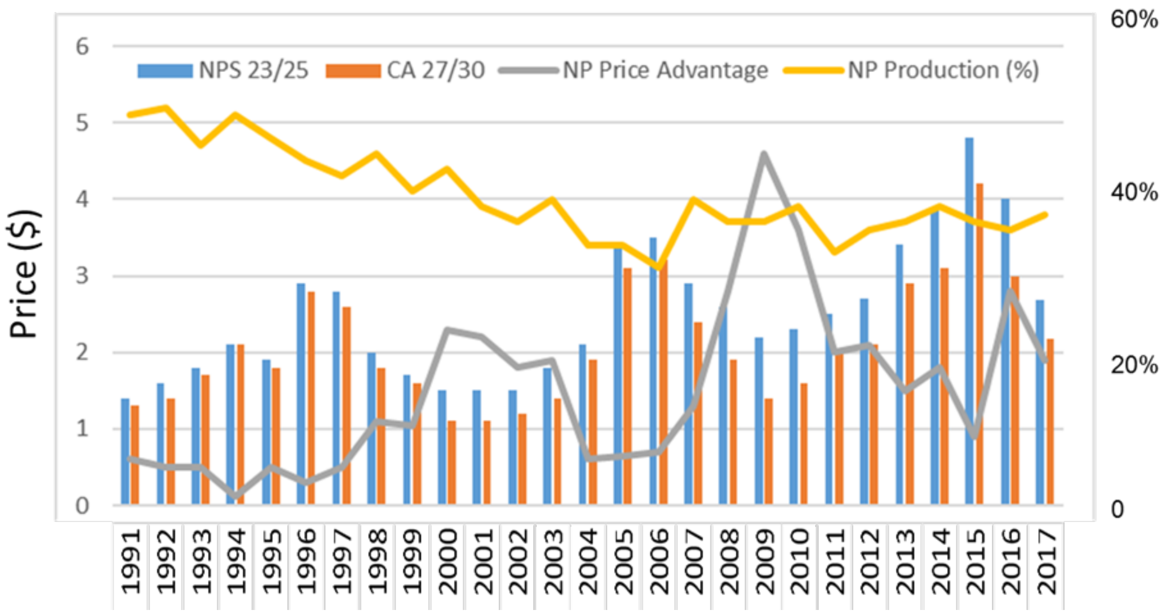

Figure 1. Production and marketing trends of Nonpareil versus other California cultivars (adapted from N.T. Ryan, citation 1, chapter 19).

During periods of low market prices, the Nonpareil price advantage consistently increased, further demonstrating the enduring value of this variety. The acreage of Nonpareil is inherently limited by its self-sterility, requiring pollinizer varieties. Typically, two or more pollinizers are inter-planted to provide good coverage of early as well as late Nonpareil bloom and to diversify harvest times to allow more efficient farming operations. Ideally, a range of self-fruitful Nonpareil-type varieties derived from diverse breeding sources to reduce crop vulnerability to disease/insect/environmental damage (associated with genetic inbreeding) is desirable. [California almond production is currently very vulnerable to genetic inbreeding because most pollinizers have Nonpareil and Mission as direct parents]. Because Nonpareil's dominance is established by superior performance in a range of production, resistance, and market traits, replacement varieties demonstrating comparable performance are at least 20 years away

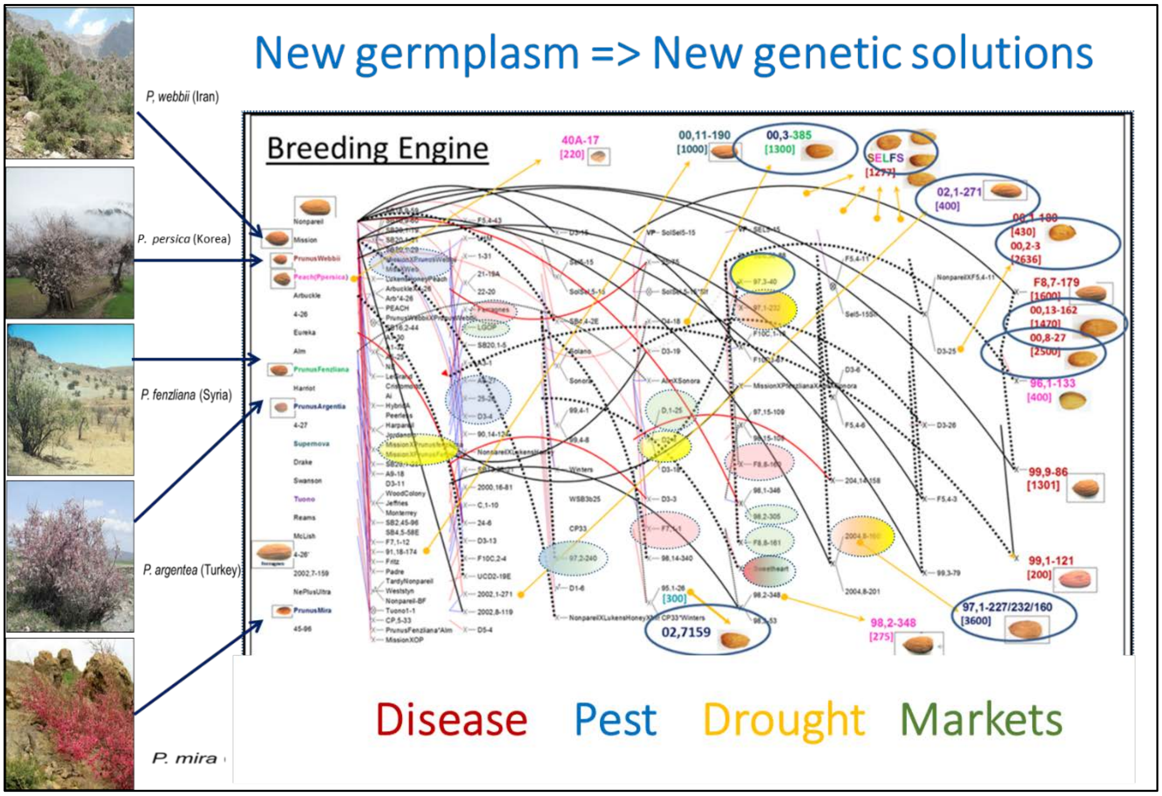

Figure 2. Summary of the UCD breeding germplasm pedigrees from diverse and often wild almond and related species parents (left column) used to develop advanced selections currently being tested in regional variety and grower trials (circled items). Lines connect progeny to parents; solid lines identify seed parent while dotted lines identify the pollen parent. The highlighted color-coded ovals bounded by dotted lines identify breeding parents demonstrating desirable characteristics for resistance to disease, pests and drought as well as new opportunities for market expansion. Current (2018) breeding progeny are 1 to 3 generations beyond that shown in **figure 2** because 6 to 10 years small-scale regional grower testing to rogue out latent variety deficiencies is routinely practiced prior to advancement to formal RVT.

(given that at least 10 years of regional testing is prudent before new variety release). Consequently, the more immediate goal of the breeding program is to develop improved pollinizers for Nonpareil. Because Nonpareil is self-sterile, both pollinizers (trees) as well as pollinators (bees) will be required in any near-future Nonpareil-based orchard. Because pollinator bees will be required for the Nonpareil trees, the major advantage of self-fruitful varieties is for as early bloom pollinizers. Ideally, the early pollinizer should consistently bloom several days before Nonpareil to prime honeybee cross-pollination activity. Self-compatibility (self-pollen able to set self-fruit) would be particularly desirable early pollinizers since other cross-pollinizers have yet to bloom and provide it with cross-compatible pollen. [Consistent self-fruitfulness results from self-compatibility as well as autogamy (the capacity for consistent self-pollination or high-volume transfer of pollen from the anter to the stigma of the same flower). Because at least some cross-pollinating honeybees will need to be present for the Nonpareil trees, self-compatibility in early blooming pollinizers will be most important with consistent self-pollination useful but not essential.] UCD breeding methods and strategies thus target self-compatible early Nonpareil bloom pollinizers with improved traits including disease and stress resistance, and subsequently improve, self-fruitful varieties demonstrating Nonpareil productivity and quality but flowering throughout the standard bloom season. The program is also pursuing very late blooming varieties for regions where frost-avoidance is desirable.

A general overview the UCD Almond Breeding Program methods and strategies is presented in (**Figure 2)**. To incorporate self-fruitfulness, of range of new genes have been brought in from related species. (This is required because self-fruitfulness is not naturally present in either cultivated almond or its parent species *Prunus dulcis*). This breeding approach has also brought in a range of both desirable (including resistance to diseases, pests and environmental stresses as well as new market options {highlighted lineages in **Figure 2**}) as well as undesirable traits such as bitterness and small kernel size. The challenge is to maintain and advance desirable traits while roguing out undesirable genes in the ongoing selection process to transform wild germplasm into California adapted varieties. A summary of promising new traits as well as overall performance of advanced breeding selections is provided in the following Results and Discussion section.

Table 1. Summary of breeding crosses and seed/seedling development from 2017 and 2018.

	2017	**2018**++
Total crosses	>26,000	~22,000
Recovered seed	~10,000	~8,000
Transplanted seedlings	4,574	
Greenhouse seedlings	5,415	
Seed in stratification	~1,000	
Seed in storage	~2000	

[++ Data for recovered seed in 2018 is a preliminary estimate since the 2018 harvest as just beginning]

Results and Discussion:

<u>Generate new seedling progeny.</u>
A summary of breeding crosses generated in 2017 and 2018 is presented in (**Table 1**). While we continue to meet our targets for generating breeding seed, a high proportion (approximately 25-35 %) continue to lose in field plantings during the first 2 seasons either from deliberate roguing of undesired tree architectures or from disease and/or rodent damage (considered part of the selection process). To reduce these losses, we are also experimenting with novel seed planting and transplanting schemes, which inevitably result in higher seedling losses until the problems, are worked out. The extent of these losses is largely anticipated and compensated by increases in plantings densities. Of the 2018 crosses, approximately 80% continue to target further advancement of elite lines (such as those derived from current RVT selections) with the remaining used for additional

crosses to earlier, intermediate germplasm to enrich the breeding material for desired disease/pest/stress resistance (**Figure 2**). Promising results from 2017/18 are summarized below with additional information available in earlier annual reports.

Targeted traits.

Many traits are targeted by breeding selection with an initial emphasis on those conferring Nonpareil-type kernel quality and orchard productivity. Because wild germplasm will lack many desired genes for required quality and productivity, and in addition, will possess many undesirable genes such as small kernel size and peach-type shells, early breeding progress is typically pursued through a series of recurrent backcrossing to California-adapted germplasm such as Nonpareil while simultaneously selecting for the desired exotic trait such as self-fruitfulness. The advanced breeding germplasm summarized in **Figure 2** has achieved good kernel quality and adaptability to California conditions through this approach, while still retaining a large genetic diversity, as documented in described in the 2016/17 annual report. The relatively low proportion of this exotic germplasm in these advanced breeding lines means it will be rapidly lost with continued backcrossing, requiring more specialized breeding methods such as marker -assisted inter-crosses to capture these traits in more advanced selections. Several traits showing improved disease, pest, and/or environmental stress

Figure 3. Rating scale (0-5) of shoots from UCD plantings at the Chico RVT collected at a temperature of 100+ F and held for 24 hours in the shade with a rating of 0 showing no leaf distortion or brittleness to a rating of 5 showing both high leaf distortion and leaf brittleness.

resistance appear to be segregating in this germplasm and so potentially available to further transfer under appropriate selection (see previous annual reports). The 2016/17 annual report described possible differences in water-use efficiency/drought tolerance in this diverse breeding lineages, which were identified by retaining breeding progeny plots for an additional year of evaluation but without any supplementary water (zero-irrigation). The wild species *Prunus fenzliana* (a progenitor species to cultivated almond, *P. dulcis*) was found to be a promising source for such resistance but because these

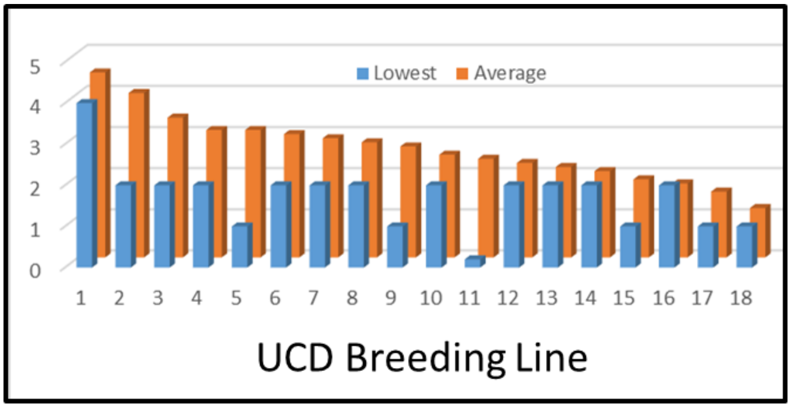

Figure 4. Results from the Detached-Shoot Desiccation Testing of 18 advanced breeding lines showing that populations demonstrating low average scores also contained the lowest scoring individuals (with a few interesting exceptions).

Selection-Chico	Avg. Rating
UCD1-271	4.5
UCD8-201	4.5
Sweetheart	4
UCD18-20	4
UCD8-27	4
Winters	4
2-19E Kester	3.5
UCD8-160	3.5
Nonpareil	3
UCD1-16	3
UCD1-232	2.5
UCD7-159	2.5
UCD3-40	2
Selection- Nickels	**Rating**
F8,8-160	4
F8,8-161	2
D3-26x	3
F8,8-4	2
LGop	4
97,2-240	2
97,15-109	3
UCD3-40	3
98,14-340	1
UCD1-16	3
D1-6	1
98,3-53	0

Figure 5. Results from replicated Detached-Shoot Desiccation Testing of advanced UCD RVT selections.

were owned-rooted progeny trees, the specific contribution of roots versus shoots could not be determined. Also discussed in earlier annual reports were differences in Critical Leaf Temperatures (as an indicator of water use efficiency) in advance breeding lineages as determined in a project with Dr. Matthew Gilbert, where advanced lineages derived from the wild species *Prunus webbii* also showed promise. In 2018, we began to experiment with the simpler and more direct analysis of taking shoot cuttings on 100+ degree days and rating the amount of desiccation/leaf collapse after 24 hours (**Figure 3**). Results from an analysis of 18 diverse own-rooted breeding lineages are shown in (**Figure 4)**, which suggest that, in general, lineages showing low population averages also tended to have the lowest-scoring individuals (though interesting exceptions occurred). In one of these seedling populations, the drip-line irrigating that tree row was accidentally cut, resulting in a number of trees showing distinct terminal shoot water-stress by the time the irrigation loss was identified. Interestingly, individual tree ratings for the degree of water stress also correlated well with results from the detached shoot desiccation test (though, again, an interesting exception occurred). Replicated testing of advanced UCD breeding selections being grown at the Chico RVT (4th leaf) and Nickels Research Farm in Arbuckle, California (12 leaf) gave results that were consistent between replications (**Figure 5**) and were in general agreement with the earlier Critical Leaf Temperature analysis by Matthew Gilbert. As with earlier zero-irrigation and critical- leaf-temperature assessments, advanced breeding lineages derived from *P fenzliana* and *P webbii* showed special promise. Because of the advanced breeding stage of most of these individuals and lineages (including UCD selection 98,3-53), positive contributions from multiple genetic sources are likely. Of particular significance is the finding of sizable differences, including very low heat stress scores in the advanced RVT selections, as it indicates a successful incorporation of improved stress resistance into advanced, high quality California-adapted selections.

Examples of disease resistance include the higher levels of leaf rust resistance observed in advanced UCD selections derived from *P webbii* observed in a 2017 outbreak (**Figure 6**, described in the 2016/17 annual report). Additional examples of disease resistance are commonly observed breeding plots such as the segregation for blight resistance observed in an advanced UCD breeding lines derived from the wild peach, *P mira* (**Figure 7**). The ideal resistance would be controlled by a single dominant gene which greatly facilitates its selection and transfer to advanced, California-adapted selections. Typically, a more complex genetic control is involved making selection and transfer more difficult. Molecular-marker analysis can be particularly useful in this case, as it not only verifies a genetic basis but also provides information on the complexity of control and so the relative difficulty for further transfer. **Figure 8** shows results from a long-term collaboration with Dr. Sathe at the University of Florida where molecular analysis is utilized to accurately characterize vulnerabilities to both aflatoxin contamination and kernel allergenicity in different stages of our incorporation of wild germplasm to advanced breeding selections (see also earlier annual reports and citation 5). Occasionally, exotically derived, desirable traits are found to be strongly heritable indicating a simple genetic control as well as possible genetic dominance. An example is the identification of a major gene for botryosphearia resistance identified in a similar collaboration with Dr. José Chaparro University of Florida, where we are currently in the final stage of developing molecular markers to more precisely manipulate this trait (see 17. Hort10.Rootstock Breeding 2017/18 annual report). Another example can be seen in the wild peach and wild almond control of self-compatibility. Although differing in mechanism and so possible final efficacy, both are controlled by a single dominant gene and so are relatively easily transferred using traditional breeding techniques and our previously developed molecular markers as described in earlier reports and citations 8, 14 and 15. Unfortunately, control for the complementary autogamy (self-pollination) trait is much more complex and can be highly variable under different environments. Thus, while the relatively easy transfer of the self-compatibility gene to almond would make it technically

	Leaf Rust
Nonpareil	3.4
UCD8-160	2.1
UCD1-232	1.3

Figure 6. Differences in leaf rust damage in P webbii derived advanced selections when compared to Nonpareil.

Figure 7. Blight resistance segregating in a *P. mira* derived UCD breeding line.

	Aflatoxin
Nonpareil	308
UCD8-161	178

	Allergenicity
Nonpareil	1.02
UCD-LGOP	0.49
Peach	0.39

Figure 8. Documented tolerance to aflatoxin contamination (left) and kernel allergenicity (right) and advanced breeding lines derived from *Prunus persica* (cultivated peach).

self-fruitful, the development of a consistent commercial-level self-fruitfulness (i.e., a consistently high level of self-pollination and seed set even without added honeybee pollinators) would be much more complex and so require extensive and multi-year regional field testing to determine actual performance.

Other exotic traits may be controlled by 1 to a few dominant genes and so relatively easily transferred to advanced almond types. An example is seen in the 'web-trait' derived from P webbii and described in earlier reports. This trait is highly heritable, with a large proportion of backcross progeny expressing the trait regardless of genetic and environmental backgrounds. The web-trait is characterized by a thin, highly-lignified shell resulting in high shell-seal with kernel/nut crack out proportions as high as 70% (**Figure 9**). The opportunity for unique durable shell-sculpturing also presents opportunities for market expansion, such as the Peerless market where attractive shell sculpturing desired. Because the trait is also associated with the earlier shell/endocarp lignification during fruit development, this trait may also confer improved resistance to hull-rot associated shoot trait die-back because early lignification appears to acts as a barrier to pathogen transfer from the fruit to the shoot. Other opportunities for niche market expansion include new varieties expressing desirable levels of amaretto flavor, as in advanced selection UC-D 1-25, or high Marcona-like roasting quality as in the Sweetheart variety.

Figure 9. Advanced breeding line showing the web-trait derived from P webbii, characterized by a thin, highly lignified and well-sealed shell. [Inset shows web-trait nut cross-section].

New traits also offer the opportunity radically modifying traditional orchard management practices to meet emerging industry/consumer demands. For example, concerns related to potential consumer health contaminants (salmonella, etc.) as well as orchard dust management have spurred interest in the development of alternative harvest methods such as a catch-frame systems similar to that used with pistachio. History has shown that such innovations in mechanization require similar innovations in terms of plant architecture. Because of the extensive infusion the highly diverse germplasm from sources ranging from wild peach wild almond, a similarly diverse range of tree architectures has become available which

Figure 10. Advanced California-adapted, good kernel quality breeding lines showing a range of tree architectures from pillar-types with a strong spur bearing-habit (left) to compact trees with dard-type lateral shoots (center) to dwarf trees with mixed bearing habits (left).

is also well adapted to California production conditions and market requirements for kernel quality (**Figure 10**). Similarly, novel options are also becoming available terms of crop bearing-habits more amenable to over-tree harvest systems such as the apple-like dard-bearing habit in **Figure 10**, center. In-orchard, at-harvest hulling has also been proposed for future catch frame systems to avoid the otherwise significant problem of fruit drying/dehulling. A range of genetic options controlling harvest/post harvest fruit characteristics are similarly becoming available which may facilitate such operations. These include thinner and easily desiccated hulls, as are found IXL and some heirloom varieties such as 'California', as well as more novel genetic modifications such as early separation the inner from outer almond shell/hull, complete absence of the outer shell and its vascular attachments to the hull, to the complete separation of the inner shell at maturity allowing direct access to the kernel {but also to pests and disease} (**Figure 11**).

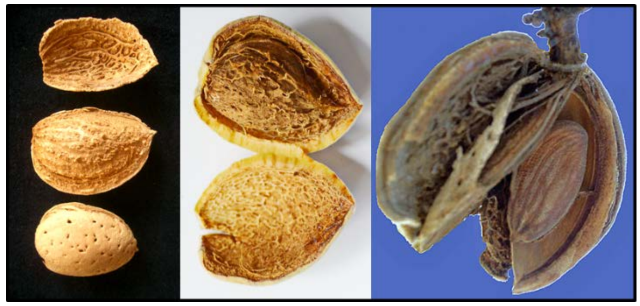

Figure 11. Examples of genetic modifications to facilitate development of sustainable harvest technologies, such as consistent separation the inner and outer almond shell/hull (left), absence of the outer shell and its vascular attachments to the hull (center), and the complete separation of the inner shell at maturity, allowing direct access to the kernel (right).

Yield determination

A summary of 2017 kernel yields for all selections in the Chico State, Salida, and Chowchilla RVT's is presented in **Figures 12, 13 and 14**, respectively. Also shown are canopy photosynthetically active radiation (PAR) light interception, yield per unit PAR, and 2016/2017 cumulative yield as determined by B. Lampinen. A more complete data and analysis is available in his 17-Hort2-Lampinen-Field Evaluation of Almond Varieties 2017/18 annual report. Trees were planted in 2014 and so would be at third leaf. Trees at the Chico State, Salida and Chowchilla RVT trials were planted on Krymsk 86, Nemaguard and Hansen 536 rootstocks respectively with alternate rows being planted with Nonpareil. There are four replications of each of the selections at each of the three RVT sites. Yield trends in the Butte and Stanislaus County RVTs tended to be similar, with 2017 representing the first sizable yields. Yields in 2016 were relatively light owing to the young age of the trees and the often-rainy conditions during bloom. Much higher yields and a distinctly different production trend are observed in results from the Madera RVT. This is partly due to the higher density of plantings as well as propagation on the very vigorous Hansen rootstocks. A good general relationship is observed between yield and PAR data at all three sites, though with exceptions. High sticktight/mummy counts were observed at all sites, particularly for high-yielding UCD selections. In 2017, many selections were harvested too early because of limited harvest/labor, which would

Butte

# reps	Variety or selection	Yield (kernel lbs/ac)	
124	**Nonpareil**	**2145**	**a**
4	Winters	2040	a b
4	Booth	1982	a b c
4	UCD18-20	1933	a b c
4	UCD1-232	1869	a b c
4	UCD8-160	1708	a b c d
2	Y121-42-99	1597	a b c d e
4	Folsom	1583	a b c d e
4	Jenette	1524	a b c d e f
4	Y117-91-03	1500	a b c d e f
4	Capitola	1500	a b c d e f g
4	UCD8-201	1405	b c d e f g
4	Wood Colony	1382	b c d e f g
4	Durango	1271	c d e f g h
4	Self-fruitful P13.019	1117	d e f g h i
4	Kester (2-19e)	1114	d e f g h i
4	UCD8-27	1105	d e f g h i
4	Eddie	1090	d e f g h i
4	Kester (2-19e) /Hansen	1060	d e f g h i
4	Aldrich	1031	d e f g h i
4	UCD7-159	1019	d e f g h i
4	UCD1-16	964	d e f g h i
4	Y117-86-03	932	e f g h i
4	Sterling	922	e f g h i
4	Bennett	902	e f g h i
4	Y116-161-99	823	f g h i
4	Supareil	773	f g h i
4	UCD3-40	735	g h i
3	self-fruitful P16.013	712	g h i
4	Sweetheart	526	h i
4	UCD1-271	405	i

# reps	Variety or selection	Midday canopy PAR interception (%)	
4	Kester (2-19e) /Hansen	67.3	a
4	Capitola	66.1	a b
4	UCD18-20	62.4	a b c
4	Y117-91-03	60.5	a b c d
4	Kester (2-19e)	59.5	a b c d
124	**Nonpareil**	**59.1**	**a b c d e**
4	Booth	58.2	b c d e f
4	Self-fruitful P13.019	57.7	b c d e f
4	Sterling	55.6	c d e f g
4	Folsom	55.6	c d e f g
4	Winters	55.5	c d e f g
4	Supareil	55.1	c d e f g
4	Sweetheart	54.3	c d e f g h
4	Durango	54.2	c d e f g h
4	UCD3-40	51.7	d e f g h i
4	UCD1-16	50.6	e f g h i j
4	UCD7-159	50.5	e f g h i j
4	Y117-86-03	49.6	f g h i j
4	UCD8-201	49.5	f g h i j
4	UCD8-27	48.8	g h i j k
4	Eddie	48.3	g h i j k l
4	UCD1-232	47.4	g h i j k l
4	Aldrich	46.6	h i j k l
4	Jenette	44.5	i j k l m
4	Y116-161-99	42.6	j k l m n
2	Y121-42-99	41.0	k l m n o
4	Bennett	40.7	k l m n o
4	Wood Colony	40.2	l m n o
4	UCD8-160	37.7	m n o
4	UCD1-271	37.1	m n o
4	self-fruitful P16.013	35.3	n o

# reps	Variety or selection	Yield per unit PAR intercepted	
3	UCD8-160	43.1	a
3	UCD1-232	41.6	a
2	Y121-42-99	38.9	a b
155	**Nonpareil**	**35.9**	**a b c**
4	Wood Colony	34.4	a b c d
4	Jenette	34.3	a b c d
2	Winters	34.3	a b c d
4	Booth	34.2	a b c d
3	UCD18-20	30.3	a b c d e
4	UCD8-201	29.5	a b c d e f
4	Folsom	28.7	a b c d e f
4	Y117-91-03	24.8	b c d e f g
4	Durango	23.1	c d e f g
4	UCD8-27	22.8	c d e f g
4	Capitola	22.6	c d e f g
4	Aldrich	22.1	c d e f g h
4	Eddie	21.5	c d e f g h
4	Bennett	20.9	c d e f g h
4	Y116-161-99	20.2	d e f g h
4	UCD7-159	20.2	d e f g h
3	self-fruitful P16.013	19.8	d e f g h
4	Self-fruitful P13.019	19.4	d e f g h
4	UCD1-16	19.0	d e f g h
4	Kester (2-19e)	18.8	d e f g h
3	Sterling	18.5	e f g h
4	Y117-86-03	18.5	e f g h
4	Kester (2-19e) /Hansen	15.6	e f g h
4	Supareil	14.0	f g h
4	UCD1-271	10.9	g h
4	Sweetheart	9.2	g h
4	UCD3-40	6.7	h

Cumulative 2016-2017

Butte

# reps	Variety or selection	Yield (kernel lbs/ac)	
4	Booth	2778	a
4	UCD18-20	2650	a b
4	UCD1-232	2581	a b c
108	**Nonpareil**	**2579**	**a b c**
4	Winters	2509	a b c d
4	UCD8-160	2379	a b c d e
4	Folsom	2106	a b c d e f
4	Y117-91-03	1981	b c d e f g
4	Capitola	1955	b c d e f g
4	UCD8-201	1922	c d e f g h
4	Self-fruitful P13.019	1881	c d e f g h
4	Wood Colony	1801	d e f g h i
4	Jenette	1795	d e f g h i
4	Kester (2-19e)	1763	e f g h i
4	Kester (2-19e) /Hansen	1669	e f g h i
4	Durango	1662	e f g h i
4	UCD8-27	1612	f g h i
4	Eddie	1537	f g h i j
4	UCD1-16	1520	f g h i j
4	Y117-86-03	1392	f g h i j
4	Y116-161-99	1352	g h i j
4	Aldrich	1347	g h i j
3	self-fruitful P16.013	1314	g h i j
4	Sterling	1258	g h i j k
4	UCD7-159	1230	g h i j k
4	Bennett	1193	h i j k
4	Supareil	1081	i j k
4	UCD3-40	1077	i j k
4	Sweetheart	838	j k
4	UCD1-271	565	k

Figure 12. Kernel yield, canopy photosynthetically active radiation (PAR) interception, and yield per unit PAR for the Chico State (Butte County) RVT. (Letters indicate significant difference between selections: selections possessing common letters are not different significantly based on data from these replicated trials).

Stanislaus

# reps	Variety or selection	Yield (kernel lbs/ac)	
4	UCD8-160	2058	a
4	UCD18-20	1971	a b
4	Y117-91-03	1918	a b c
4	Self-fruitful P13.019	1783	a b c d
4	Aldrich	1675	a b c d e
4	Kester (2-19e)	1648	a b c d e
4	Kester (2-19e) / Hansen	1600	a b c d e
4	UCD8-201	1569	a b c d e
4	Booth	1550	b c d e f
4	Winters	1544	b c d e f
4	Y117-86-03	1536	b c d e f
4	Bennett	1473	b c d e f G
3	Durango	1467	b c d e f g
3	Sterling	1465	b c d e f g
4	Y116-161-99	1437	c d e f g h
4	UCD7-159	1417	c d e f g h i
4	Y121-42-99	1411	c d e f g h i
4	**Nonpareil**	**1408**	**c d e f g h i**
4	UCD1-232	1404	c d e f g h i
4	Jenette	1396	d e f g h i
4	Capitola	1365	d e f g h i
4	Eddie	1285	d e f g h i
4	self-fruitful P16-013	1252	e f g h i
4	Folsom	1241	e f g h i
4	UCD1-271	1234	e f g h i
4	UCD1-16	1223	e f g h i
4	Supareil	1042	f g h i
4	UCD3-40	1016	g h i
4	Sweetheart	936	h i
4	UCD8-27	907	i

# reps	Variety or selection	Midday canopy PAR interception (%)	
4	Kester (2-19e) / Hansen	55.1	a
4	Y117-91-03	53.4	a b
4	Booth	50.1	a b c
4	Self-fruitful P13.019	49.8	a b c
4	Sweetheart	49.6	a b c d
4	Sterling	48.6	a b c d e
4	Folsom	48.2	a b c d e f
4	Capitola	46.4	a b c d e f g
4	UCD18-20	46.0	b c d e f g
4	Y121-42-99	45.9	b c d e f g
4	UCD3-40	45.9	b c d e f g
4	Supareil	45.9	b c d e f g
4	Eddie	45.6	b c d e f g
4	UCD1-16	45.2	b c d e f g
4	Winters	44.7	b c d e f g
4	Kester (2-19e)	43.2	c d e f g
4	UCD1-271	42.5	c d e f g
4	UCD1-232	41.9	c d e f g
4	Y116-161-99	41.3	c d e f g
4	Bennett	41.1	c d e f g
4	Jenette	40.9	c d e f g
4	Y117-86-03	40.4	d e f g
4	UCD7-159	40.0	e f g
4	Aldrich	39.9	e f g
4	UCD8-27	39.8	e f g
124	**Nonpareil**	**39.5**	**e f g**
4	UCD8-201	39.1	f g
4	Durango	38.9	f g
4	self-fruitful P16-013	38.1	g
4	UCD8-160	37.7	g

# reps	Variety or selection	Yield per unit PAR intercepted	
4	UCD8-160	54.2	a
4	UCD18-20	42.8	b
4	Aldrich	41.7	b c
4	UCD8-201	39.6	b c d
4	Y117-86-03	38.8	b c d e
3	Durango	37.9	b c d e f
4	Kester (2-19e)	37.7	b c d e f g
4	**Nonpareil**	**37.7**	**b c d e f g**
4	Self-fruitful P13.019	36.0	b c d e f g h
4	Y117-91-03	35.9	b c d e f g h
4	Bennett	35.2	b c d e f g h
4	UCD7-159	35.2	b c d e f g h
4	Y116-161-99	34.6	b c d e f g h
4	Winters	34.4	b c d e f g h
4	Jenette	34.1	c d e f g h i
4	UCD1-232	33.6	c d e f g h i
4	UCD1-16	33.1	c d e f g h i
4	self-fruitful P16-013	33.0	d e f g h i
4	Booth	30.6	e f g h i j
4	Y121-42-99	30.4	e f g h i j
3	Sterling	29.9	f g h i j
4	Kester (2-19e) / Hansen	29.1	g h i j
4	Capitola	29.0	g h i j
4	UCD1-271	28.9	h i j
4	Eddie	28.2	h i j
4	Folsom	25.8	h i j k
4	Supareil	22.9	j k
4	UCD8-27	22.8	j k
4	UCD3-40	22.2	j k
4	Sweetheart	18.8	k

Cumulative 2016-2017

Stanislaus

# reps	Variety or selection	Yield (kernel lbs/ac)	
4	UCD8-160	2282	a
4	Self-fruitful P13.019	2243	a b
4	UCD18-20	2233	a b
3	Kester (2-19e)	2127	a b c
4	Y117-91-03	2096	a b c d
4	Aldrich	1837	a b c d e
3	Kester (2-19e) /Hansen	1809	a b c d e
4	Bennett	1808	a b c d e
4	Y121-42-99	1785	a b c d e
4	Y116-161-99	1763	a b c d e
4	Y117-86-03	1749	a b c d e f
4	Winters	1739	a b c d e f
4	UCD8-201	1692	a b c d e f g
4	Booth	1678	b c d e f g h
3	Durango	1633	c d e f g h i
4	UCD1-232	1629	c d e f g h i
4	Eddie	1595	c d e f g h i
4	**Nonpareil**	**1587**	**c d e f g h i**
4	UCD1-16	1580	c d e f g h i
4	Folsom	1522	d e f g h i
4	Jenette	1515	d e f g h i
3	Sterling	1497	d e f g h i
4	Capitola	1488	e f g h i
4	UCD7-159	1456	e f g h i
4	self-fruitful P16-013	1401	e f g h i
4	UCD1-271	1319	e f g h i
4	UCD3-40	1149	f g h i
4	Sweetheart	1115	g h i
4	UCD8-27	1085	h i
3	Supareil	1056	i

Figure 13. Kernel yield, canopy photosynthetically active radiation (PAR) interception, and yield per unit PAR for the Salida (Stanislaus Co.) RVT. (Letters indicate significant difference between selections: selections possessing common letters are not different significantly based on data from these replicated trials).

Madera

# reps	Variety or selection	Yield (kernel lbs/ac)	Significance
4	Y-116-161-99	2604	a
83	**Nonpareil**	**2341**	**a b**
4	Booth	2247	a b c
4	UCD-18-20	2226	a b c
4	Capitola	2190	a b c d
4	Eddie	2167	a b c d
4	Winters	2066	a b c d
4	Y-117-91-03	2042	a b c d
4	Bennett	1977	a b c d e
4	Self-fr-P16-013	1931	a b c d e
4	Sterling	1889	a b c d e f
4	Kester (2-19e)	1840	b c d e f
4	Durango	1827	b c d e f
4	Folsom	1818	b c d e f
4	Y-117-86-03	1807	b c d e f
4	Supareil	1791	b c d e f g
4	Jenette	1783	b c d e f g
1	Y-121-42-99	1758	b c d e f g
4	UCD-8-201	1671	b c d e f g
4	UCD-1-16	1647	b c d e f g
4	UCD-8-160	1596	b c d e f g
4	UCD-1-232	1490	c d e f g
4	UCD-7-159	1465	c d e f g
4	Self-fr-P13-019	1417	d e f g h
4	Aldrich	1413	d e f g h
4	Sweetheart	1210	e f g h i
4	UCD-1-271	1137	f g h i
4	UCD-8-27	1022	g h i
4	UCD-3-40	708	h i
4	Wood Colony	675	i

# reps	Variety or selection	Midday canopy PAR interception (%)	Significance
4	Folsom	70.4	a
4	Capitola	70.2	a
4	UCD-1-271	66.0	a b
4	Sterling	65.9	a b
4	Booth	65.7	a b
4	Supareil	65.3	a b c
4	Sweetheart	64.4	a b c
4	UCD-3-40	62.6	a b c
4	Kester (2-19e)	61.5	a b c d
4	Eddie	60.5	a b c d
1	Y-121-42-99	59.1	a b c d
105	**Nonpareil**	**59.0**	**a b c d**
4	Y-117-91-03	58.7	a b c d
4	Y-116-161-99	58.5	a b c d
4	Aldrich	57.7	a b c d
4	UCD-8-27	56.0	a b c d e
4	Bennett	55.2	a b c d e
4	Self-fr-P16-013	54.7	a b c d e
4	Durango	52.9	b c d e
4	UCD-18-20	52.9	b c d e
4	Self-fr-P13-019	52.8	b c d e
4	UCD-7-159	52.5	b c d e
4	Y-117-86-03	52.3	b c d e
4	UCD-8-201	51.7	b c d e
4	Jenette	51.6	b c d e
4	Winters	51.0	b c d e
4	UCD-1-232	49.5	c d e
4	UCD-1-16	46.1	d e
4	UCD-8-160	46.0	d e
4	Wood Colony	41.2	e

# reps	Variety or selection		Significance
4	Y-116-161-99	44.5	a
4	UCD-18-20	41.8	a b
84	**Nonpareil**	**40.7**	**a b**
4	Winters	39.7	a b c
4	Bennett	36.5	a b c d
4	UCD-1-16	36.2	a b c d e
4	Self-fr-P16-013	36.0	a b c d e
4	Eddie	35.5	a b c d e
4	UCD-8-160	35.5	a b c d e
4	Y-117-91-03	35.1	a b c d e
4	Durango	34.7	a b c d e
4	Jenette	34.6	a b c d e
4	Y-117-86-03	34.6	a b c d e
4	Booth	34.1	a b c d e
4	UCD-8-201	32.0	b c d e
4	Capitola	31.3	b c d e
4	UCD-1-232	29.9	c d e
4	Kester (2-19e)	29.9	c d e
1	Y-121-42-99	29.7	c d e
4	Sterling	28.5	d e
4	Supareil	27.6	d e f
4	UCD-7-159	26.9	d e f g
4	Self-fr-P13-019	26.0	d e f g h
4	Folsom	25.7	e f g h
4	Aldrich	25.4	e f g h
4	UCD-8-27	18.1	f g h i
4	Sweetheart	17.6	g h i
4	UCD-1-271	17.2	g h i
4	Wood Colony	16.7	h i
4	UCD-3-40	11.5	i

Cumulative 2017-2018

Madera

# reps	Variety or selection	Yield (kernel lbs/ac)	Significance
3	Y-116-161-99	4782	a
4	Booth	4103	a b
4	Capitola	3971	a b c
4	UCD-18-20	3905	a b c d
4	Self-fr-P16-013	3842	a b c d
4	Y-117-86-03	3801	a b c d
4	Bennett	3747	a b c d e
83	**Nonpareil**	**3641**	**b c d e f**
4	Kester	3623	b c d e f
4	Y-117-91-03	3469	b c d e f g
4	Winters	3435	b c d e f g
4	Eddie	3429	b c d e f g
4	Jenette	3427	b c d e f g
1	Y-121-42-99	3290	b c d e f g h
4	Durango	3242	b c d e f g h i
4	Aldrich	3137	b c d e f g h i
4	UCD-1-16	3116	b c d e f g h i
4	Self-fr-P13-019	3023	b c d e f g h i
4	Sterling	3001	b c d e f g h i
4	UCD-8-201	2981	c d e f g h i
4	Folsom	2870	c d e f g h i
4	Supareil	2801	d e f g h i
4	Sweetheart	2639	e f g h i
4	UCD-8-160	2559	f g h i
4	UCD-1-232	2444	g h i j
4	UCD-7-159	2240	h i j k
4	UCD-8-27	2167	i j k
4	UCD-1-271	1546	j k
4	UCD-3-40	1285	k l
2	Wood Colony	587	l

Figure 14. Kernel yield, canopy photosynthetically active radiation (PAR) interception, and yield per unit PAR for the Chowchilla (Madera County) RVT. (Letters indicate significant difference between selections: selections possessing common letters are not different significantly based on data from these replicated trials).

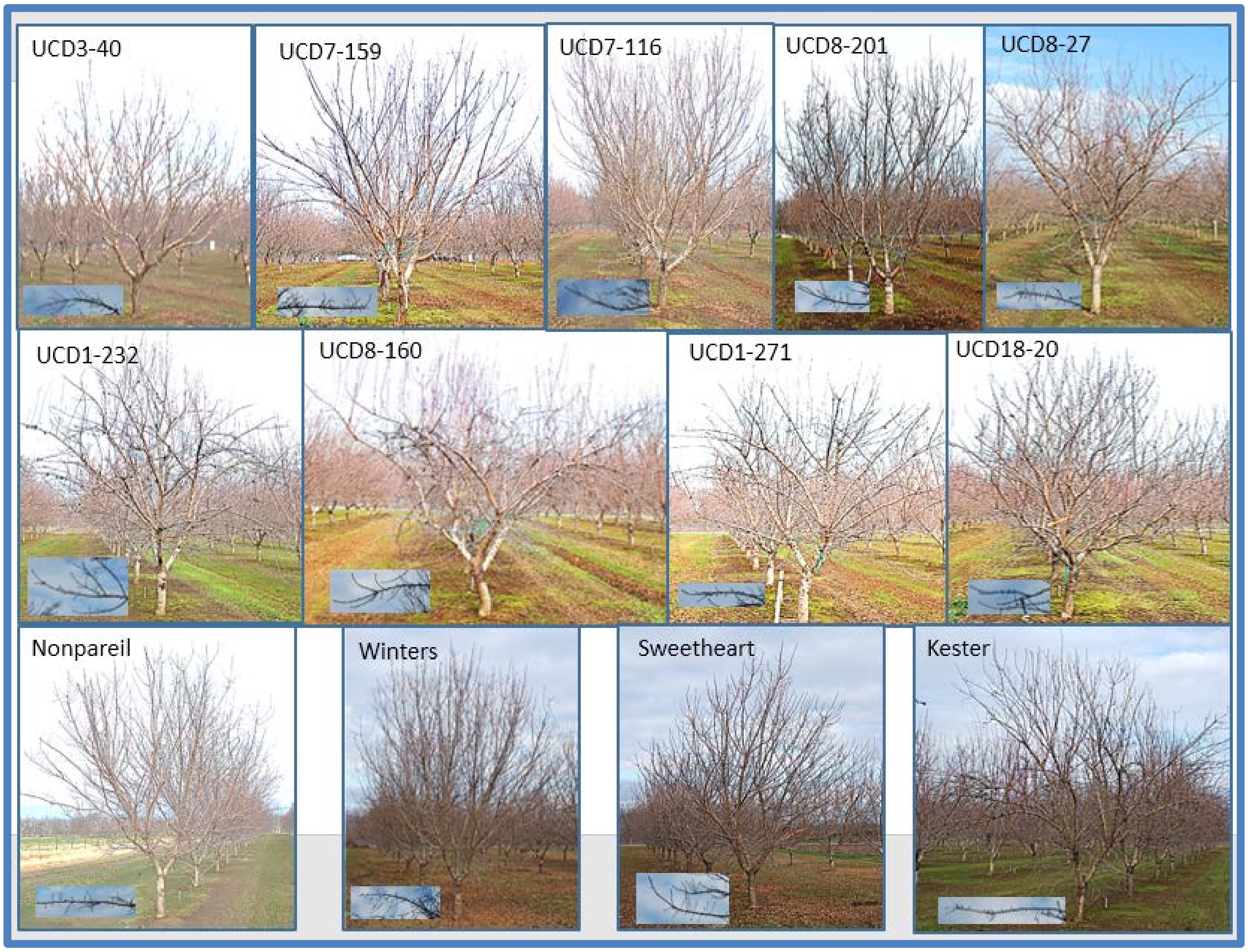

Figure 15. Tree architectures of UCD selections in the Chico State RVT following the 2017 crop with insets showing close-up of typical branching pattern.

have contributed the problem. More and better time to harvest a plant for 2018 allowing a more accurate assessment problem of the seriousness of this problem for different varieties.

Final yield potential for individual selections is difficult to predict at this early stage since both tree architecture as well as branch bearing-habit are still being developed. Excessively high yields in early plantings may ultimately harm final cumulative yield potential if it diverts energy away from the crucial early trees scaffold and spur development.

A diverse range of tree and branch architectures was intentionally selected for RVT plantings to evaluate performance at different planting densities, on different rootstocks, and in different production regions. Tree architectures ranged from upright {Aldrich, UCD7-159} to spreading {UCD 8-160} with branch architectures ranging from strong terminal shoot bearing {UCD 18-20}, to strong spur development {Kester} to nut production primarily on lateral shoots similar to apple-type dards {Winters} (**Figure 15**). Higher early production is encouraged by strong peach-type terminal shoot bearing as well as spreading tree architectures, but these may limit subsequent production if they limit transition to more efficient spur or dard type branch bearing, as well as the development of a strong tree scaffold architecture required for maximizing later production. This can be seen in the strong showing of UCD18-20 at the Butte and Stanislaus County sites where strong terminal shoot bearing allowed high early flower numbers and so higher crops in the initial years of production. Lower relative productivity is observed in the Madera site for 2017 which was in the 2nd year of significant production and so had larger and more developed trees were high yields would be more determined by a successful transition to spur bearing habit. A similar pattern is seen in the more spreading tree architectures as in UCD 8-160. The spreading architecture allowed greater early light interception as shown by the PAR data allowing greater early crop production. Unlike UCD18-20, however, UCD 8-160 appeared to leverage the larger early PAR and so carbohydrate production, to facilitate a more rapid transition to a more efficient spur and lateral shoots production. However, the spreading growth habit discouraged the early development of a more traditional Nonpareil-type tree scaffold architecture. The resulting smaller trees were thus less productive on the more vigorous environments and on the more vigorous rootstocks of the Madera site and so present challenges to traditional yield models. While successful characterization of shoot bearing habit has been achieved through the developmental model shown in (**Figure 16**). (See also annual report by G. Thorp on modified tree architectures) a similar model for tree architecture remains elusive. Traditional tree architecture models for predicting ultimate productivity, assume the early development of a strong tree scaffold structure resulting in a larger tree structure for capturing carbohydrate-producing PAR (i.e., an early investment in developing a strong structure in order to later optimize PAR capture). An alternate model, as represented by the Monterey variety and UCD 8-160, emphasizes rapid and early PAR capture, which in turn can maximize high early and subsequent yields provided sufficient energy is diverted to new growth/flower development for high subsequent yields (i.e., no alternate bearing). In the more traditional Nonpareil-type architecture, the more open scaffolds would encourage more uniform light distribution throughout the tree and so higher yield/tree volume efficiency. In the high PAR capture Monterrey-type model, the weight of the current year's crop would cause the heavily loaded branches to bend, effectively opening the interior of the tree the light interception required for spur renewal and flower induction. An inherent danger in this system is the risk of limb breakage resulting in both loss of current crop and subsequent tree bearing potential. While this was seen to some degree the Madera site, it has so far not become a serious problem.

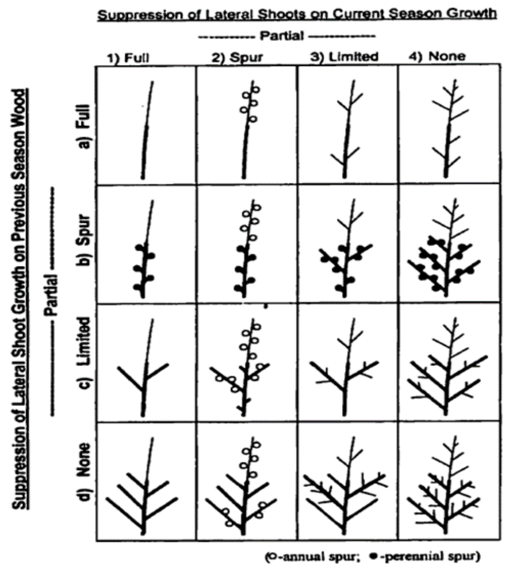

Figure 16. Developmental model used to rate range bearing habit as one determinant of final yield.

Consequently, the more spreading growth habits combined with the higher planting densities has maximized early PAR as well as orchard yields. This situation, while favorable, shows the challenges of yield analysis of entire, multi-variety orchards. A very powerful tool for the characterization of final yield potential is available in the canopy light interception models and analytical methods developed by Dr. Bruce Lampinen as it allows characterization of effective light interception regardless of tree architecture and other orchard variables. Since effective light interception has consistently been shown to be a major determinant of final orchard productivity in well-managed orchards, this approach allows us to custom design tree architectures and sizes for optimum production at the whole orchard level. Such Holistic Orchard Production Efficiency (HOPE) approaches need to consider variety interaction as well as market value differences. For example, pollinizers with smaller tree sizes such as *Carmel* and *Kester*, while producing good yields of moderate to high value kernels, also optimize light interception and so yield of adjacent premium-value Nonpareil trees (see 2016/17 annual report). Future orchard production efficiency assessments will also need to consider production under lower fertilizer and water inputs. Where PAR light interception has been the ultimate limiter of yields in current well-managed orchards, water quantity and quality will be the limit in the future. The greater diversity present in current RVT selections should allow improved insights into these future limits as well as future opportunities.

Nut and kernel quality for UCD selections and varietal standards planted at the three RVT sites is summarized in **Figure 17**. As anticipated, a range of nut and kernel characteristics was observed with most within acceptable ranges. Relatively high numbers of double kernels were observed in several selections (see appendix) and this trend will need to be monitored as trees move into mature production stages. Detailed descriptions of UCD selections in regional trials is provided in the Appendix.

Item	Site	Kernel (g)		Sealed		Hull (g)		Inshell (g)		Doubles		Twins		NOW		Blanks		Broken		Crease		Discolor		Defects	
		Avg.	*STD*	Avg.	*STD*	Avg.	*STD*	Avg.	*STD*	Avg.	*STD*	Avg.	*STD*	Avg.	*STD*	Avg.	*STD*	Avg.	*STD*	Avg.	*STD*	Avg.	*STD*	Avg.	*STD*
Aldrich	Chico	1.11	*0.0*	0.5	*0.1*	1.4	*0.1*	2.0	*0.1*	0.09	*0.0*	0.0	*0.0*	0.0	*0.0*	0.1	*0.0*	0.1	*0.0*	0.1	*0.1*	0.1	*0.0*	0.5	*0.0*
Aldrich	Chowchilla	0.94	*0.0*	0.5	*0.1*	0.9	*0.1*	1.5	*0.1*	0.01	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.1	*0.0*	0.0	*0.0*	0.3	*0.1*
Aldrich	Salida	0.97	*0.1*	0.7	*0.1*	1.3	*0.2*	1.8	*0.2*	0.05	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.1	*0.0*	0.0	*0.0*	0.1	*0.0*
Kester	Chico	1.09	*0.0*	1.0	*0.0*	2.2	*0.2*	2.2	*0.2*	0.07	*0.1*	0.0	*0.0*	0.0	*0.0*	0.0	*0.1*	0.0	*0.0*	0.2	*0.1*	0.2	*0.1*	0.6	*0.0*
Kester	Chowchilla	1.01	*0.0*	0.6	*0.3*	1.4	*0.1*	1.7	*0.1*	0.05	*0.0*	0.1	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.1	*0.0*	0.1	*0.1*	0.4	*0.1*
Kester	Salida	0.94	*0.0*	1.0	*0.0*	1.9	*0.1*	1.8	*0.1*	0.02	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.2	*0.1*
Kester/Hyb.	Chico	1.08	*0.1*	1.0	*0.0*	1.8	*0.1*	1.9	*0.1*	0.02	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.2	*0.0*	0.2	*0.0*	0.6	*0.1*
Kester/Hyb.	Salida	0.97	*0.0*	1.0	*0.0*	1.8	*0.1*	1.9	*0.0*	0.05	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.1	*0.1*	0.1	*0.0*	0.2	*0.0*
Nonpareil	Chico	1.33	*0.0*	0.5	*0.1*	2.7	*0.3*	2.1	*0.1*	0.03	*0.0*	0.1	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.2	*0.0*	0.3	*0.1*	0.6	*0.1*
Nonpareil	Salida	1.07	*0.0*	0.8	*0.1*	2.0	*0.1*	1.7	*0.1*	0.04	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.1	*0.0*	0.0	*0.0*	0.2	*0.1*
Sweetheart	Chico	1.16	*0.0*	0.8	*0.1*	2.0	*0.3*	1.8	*0.1*	0.02	*0.0*	0.1	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.1	*0.0*	0.2	*0.1*	0.6	*0.1*
Sweetheart	Chowchilla	1.08	*0.0*	0.5	*0.2*	1.8	*0.2*	1.5	*0.1*	0.02	*0.0*	0.1	*0.1*	0.0	*0.1*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.3	*0.3*	0.5	*0.2*
Sweetheart	Salida	1.09	*0.0*	0.9	*0.0*	2.2	*0.3*	1.7	*0.0*	0.01	*0.0*	0.1	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.1	*0.0*	0.0	*0.0*	0.2	*0.1*
UCD 1-16	Chico	1.28	*0.0*	0.3	*0.1*	3.4	*0.4*	2.1	*0.1*	0.18	*0.1*	0.0	*0.0*	0.0	*0.0*	0.1	*0.0*	0.0	*0.0*	0.1	*0.1*	0.3	*0.1*	0.6	*0.1*
UCD 1-16	Salida	1.01	*0.0*	0.7	*0.1*	2.1	*0.2*	1.7	*0.1*	0.11	*0.0*	0.0	*0.0*	0.0	*0.0*	0.1	*0.0*	0.0	*0.0*	0.1	*0.0*	0.0	*0.0*	0.3	*0.1*
UCD 1-232	Chico	1.29	*0.0*	0.7	*0.3*	2.2	*0.1*	3.2	*0.1*	0.21	*0.0*	0.1	*0.1*	0.0	*0.0*	0.1	*0.0*	0.1	*0.0*	0.1	*0.0*	0.3	*0.5*	0.5	*0.1*
UCD 1-232	Salida	1.12	*0.0*	0.8	*0.3*	1.9	*0.0*	2.6	*0.1*	0.05	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.1	*0.0*	0.0	*0.0*	0.4	*0.1*
UCD 1-271	Chico	1.53	*0.0*	0.2	*0.1*	2.2	*0.2*	2.7	*0.1*	0.03	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.1	*0.0*	0.5	*0.1*	0.8	*0.0*
UCD 1-271	Chowchilla	1.34	*0.1*	0.2	*0.1*	1.6	*0.2*	2.3	*0.1*	0.02	*0.0*	0.0	*0.0*	0.1	*0.1*	0.0	*0.0*	0.0	*0.0*	0.1	*0.0*	1.0	*0.1*	0.7	*0.0*
UCD 1-271	Salida	1.36	*0.1*	0.5	*0.1*	1.9	*0.0*	2.4	*0.2*	0.02	*0.0*	0.0	*0.0*	0.0	*0.1*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.3	*0.1*	0.3	*0.1*
UCD 18-20	Chico	1.46	*0.3*	0.8	*0.2*	2.0	*0.2*	3.2	*0.2*	0.32	*0.0*	0.0	*0.0*	0.0	*0.0*	0.1	*0.0*	0.0	*0.0*	0.1	*0.0*	0.0	*0.1*	0.4	*0.1*
UCD 18-20	Chowchilla	1.16	*0.2*	0.6	*0.1*	1.5	*0.4*	2.3	*0.8*	0.24	*0.2*	0.0	*0.0*	0.0	*0.0*	0.1	*0.0*	0.1	*0.0*	0.1	*0.1*	0.1	*0.0*	0.5	*0.1*
UCD 18-20	Salida	1.35	*0.1*	0.9	*0.3*	1.8	*0.1*	2.8	*0.2*	0.20	*0.1*	0.0	*0.0*	0.0	*0.1*	0.0	*0.1*	0.1	*0.0*	0.0	*0.0*	0.0	*0.1*	0.2	*0.2*
UCD 3-40	Chico	1.80	*0.3*	0.7	*0.1*	2.5	*0.5*	3.7	*0.5*	0.04	*0.1*	0.1	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.1*	0.1	*0.0*	0.1	*0.0*	0.5	*0.1*
UCD 3-40	Salida	1.61	*0.0*	0.8	*0.1*	2.4	*0.2*	3.3	*0.3*	0.03	*0.0*	0.1	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.1	*0.0*	0.0	*0.0*	0.4	*0.1*
UCD 7-159	Chico	1.80	*0.1*	0.7	*0.1*	3.0	*0.2*	2.6	*0.0*	0.01	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.1	*0.1*	0.3	*0.1*	0.7	*0.1*
UCD 7-159	Chowchilla	1.54	*0.1*	0.7	*0.1*	2.0	*0.1*	2.1	*0.1*	0.03	*0.0*	0.1	*0.0*	0.1	*0.1*	0.0	*0.0*	0.0	*0.0*	0.1	*0.0*	0.1	*0.1*	0.4	*0.0*
UCD 7-159	Salida	1.59	*0.0*	0.8	*0.1*	2.5	*0.1*	2.2	*0.1*	0.00	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.1	*0.0*	0.0	*0.0*	0.4	*0.1*
UCD 8-160	Chico	1.61	*0.0*	0.6	*0.1*	2.8	*0.1*	2.8	*0.0*	0.12	*0.0*	0.1	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.2	*0.0*	0.1	*0.0*	0.5	*0.0*
UCD 8-160	Salida	1.36	*0.0*	0.8	*0.2*	2.1	*0.1*	2.3	*0.1*	0.05	*0.0*	0.1	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.1	*0.0*	0.0	*0.0*	0.3	*0.1*
UCD 8-201	Chico	1.19	*0.1*	0.7	*0.1*	2.1	*0.3*	2.2	*0.3*	0.26	*0.2*	0.1	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.1	*0.1*	0.3	*0.1*	0.8	*0.1*
UCD 8-201	Chowchilla	0.98	*0.1*	0.4	*0.2*	1.3	*0.1*	1.8	*0.2*	0.36	*0.1*	0.1	*0.0*	0.1	*0.1*	0.0	*0.0*	0.0	*0.0*	0.1	*0.0*	0.2	*0.0*	0.7	*0.1*
UCD 8-201	Salida	1.00	*0.0*	0.9	*0.0*	1.6	*0.1*	1.7	*0.1*	0.18	*0.1*	0.1	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.1	*0.1*	0.0	*0.0*	0.5	*0.0*
UCD 8-27	Chico	1.14	*0.0*	0.3	*0.1*	2.7	*0.1*	2.0	*0.1*	0.21	*0.1*	0.2	*0.1*	0.1	*0.0*	0.0	*0.0*	0.1	*0.0*	0.1	*0.0*	0.2	*0.1*	0.6	*0.1*
UCD 8-27	Salida	1.04	*0.0*	0.4	*0.2*	2.4	*0.1*	1.8	*0.1*	0.15	*0.0*	0.1	*0.0*	0.1	*0.0*	0.0	*0.0*	0.0	*0.0*	0.1	*0.0*	0.2	*0.1*	0.5	*0.1*
Winters	Chico	1.10	*0.0*	0.6	*0.1*	1.7	*0.1*	2.1	*0.1*	0.09	*0.1*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.1	*0.0*
Winters	Salida	1.01	*0.0*	0.8	*0.1*	1.5	*0.1*	1.8	*0.1*	0.01	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.2	*0.0*
Wood Colony	Chico	1.31	*0.0*	0.8	*0.1*	1.3	*0.3*	2.5	*0.3*	0.24	*0.1*	0.0	*0.0*	0.0	*0.0*	0.1	*0.1*	0.0	*0.0*	0.2	*0.1*	0.1	*0.0*	0.7	*0.0*
Wood Colony	Chowchilla	1.25	*0.1*	0.3	*0.2*	1.4	*0.4*	1.7	*0.1*	0.04	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.0	*0.0*	0.1	*0.1*	0.2	*0.1*	0.4	*0.1*

Figure 17. Summary of average nut and kernel data from 2017 Regional Variety Trials. {Color codes are used to visualize trends within columns ranging from green (high) to read) (low)}. [Self-fruitful selections are highlighted in yellow].

All UCD self-fruitful selections except for UCD 8-201, successfully covered the targeted early Nonpareil bloom during the first 3 years of flowering (**Figure 18**). Early Nonpareil bloom-coverage however varied with year and location (see the 17-Hort2-Lampinen-Field Evaluation of Almond Varieties 2017 annual report for more detailed data). Consistent early bloom coverage in a mature Nonpareil-based orchard would be important because any Nonpareil flowers blooming earlier than the first pollinizer risk cross-pollination failures. Typically, this early bloom is also the most fecund and so makes the greatest contribution to final yield.

	# Days before or after Nonpareil Full Bloom			
Variety	**2016**	**2017**	**2018**	**Average**
UCD 3-40	-5	-12	-8	-8.3
UCD 8-27	-3	2	-1	-0.7
UCD 7-159	-2	-2	1	-1.0
Winters	-2	-2	2	-0.7
UCD 1-271	-2	4	-1	0.3
UCD 8-160	-2	-2	0	-1.3
Aldrich	-2	0	2	0
Sweetheart	-1	4	2	1.7
UCD 1-16	-1	6	-1	1.3
UCD 18-20	-1	3	5	2.3
UCD 1-232	-1	-2	3	0.0
Nonpareil	**0**	**0**	**0**	**0.0**
Wood Colony	0	4	4	2.7
Kester/Hansen	0	2	14	5.3
Kester/Krymsk 86	0	4	11	5.0
UCD 8-201	0	2	8	3.3

Figure 18. Summary of bloom initiation time relative to Nonpareil UCD selections Chico State RVT. {Yellow highlight self-fruitful selection, peach-color highlight partial self-fruitful selections}. Modified from compilation by J. Connell and L. Milliron).

Finally, a crucial factor in selecting a variety for orchard production is its market classification and associated market value. (**Table 2**) summarizes a preliminary analysis by Roger Duncan of potential crop values for various UCD RVT selections based on cumulative 2016/17 yields in Stanislaus Co., initial marketing classifications by processors and associated 2016 prices. Both yield potential and marketing classification can change as trees come into maturity.

Table 2. Summary of cumulative yield for UCD selections in the Madera RVT with estimates final market value based on market classification and 2016 prices. {* Self-fruitful}. (Modified from compilation by R. Duncan).

	Source	Cum. Yield 3rd & 4th leaf	P < 0.05	Classification	$ Value[1]
18-20	UCD	2233	ab	Monterey	$4,958
8-160*	UCD	2282	a	Wood Colony	$4,952
8-201*	UCD	1692	abcdef	Nonpareil / CA	$4551 / $3672
Kester	UCD	2127	abc	Padre / Carmel	$4532 / $4828
Nonpareil		1587	cdefghi	Nonpareil	$4,269
Aldrich		1837	abcde	CA	$3,986
1-16	UCD	1580	cdefghi	Sonora or Carmel	$3982 / $3587
Winters	UCD	1739	abcdef	Carmel	$3,948
1-232*	UCD	1629	cdefghi	CA	$3,535
7-159*	UCD	1456	efghi	CA	$3,160
1-271*	UCD	1319	efghi	CA	$2,862
3-40	UCD	1149	fghi	Carmel	$2,608
Sweetheart	UCD	1115	ghi	CA	$2,420
8-27*	UCD	1085	hi	CA	$2,354

[1]Based on Blue Diamond 2016 kernel prices

- Nonpareil $2.69
- Sonora: $2.52
- Carmel: $2.27
- Monterey: $2.22
- CA / Wood C. $2.17
- Butte / Padre: $2.14
- Mission: $2.09

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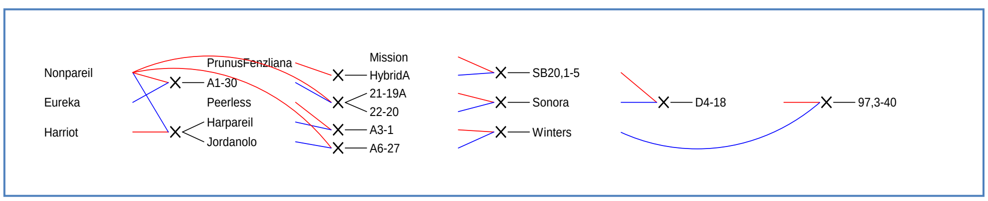
Appendix A. Characteristics of UCD selections and recent releases included in the new RVT trials including regional observations of possible defects.
[Refer to the 17-HORT2-Lampinen-Field Evaluation of Almond Varieties 2017 annual report to assess relative defect levels against standard commercial cultivars].

Kester

Kester was released as a pollinizer variety covering the economically important mid-to-late Nonpareil bloom. Over fifteen years of regional testing in all major production regions have shown *Kester* (tested as UCD 2-19E) consistently covered the later Nonpareil bloom while demonstrating a high productivity of Nonpareil-type kernels. Shell-seal is better than Nonpareil (see **Table 17**), and, while kernel shape is similar to Nonpareil, the Kester kernel tends to be smaller and has a somewhat darker seedcoat. Despite having a productivity and kernel quality comparable to Nonpareil, the size of the tree is from 15 to 25 % smaller. The smaller and more compact tree type has the advantage of allowing more sunlight to fall on adjacently planted Nonpareil rows, thus increasing Nonpareil tree size and ultimately, yield of the premium quality Nonpareil kernels. Produced 7 % double kernels the Chico RVT in 2017.

UCD3-40



UCD3-40 combines a large, high-quality kernel with good tree form and productivity. Regional testing in the Sacramento and lower San Joaquin valleys has also demonstrated good disease and pest resistance. The pedigree includes a complex parentage with a sizable contribution from *P. fenzliana,* which is often considered the species from which cultivated almond was derived. Parentage also includes *Nonpareil* and *Jordanolo*, which have a history of noninfectious bud failure. Extensive and long-term testing of this selection has thus far been free from any indication of noninfectious bud failure risk. Bloom has consistently been before *Nonpareil*, even in low chill years and was early enough in 2017 to avoid significant storm damage. The large, attractive kernels may also facilitate the development of new premium quality (*Sonora*, etc.) markets. Navel Orangeworm damage at 7% was detected in Madera RVT 2017. Greater than average hull rot at harvest was observed on UCD 3-40 at the Chico RVT in 2017. Frost damage resulting in very low sets were observed at the Madera RVT in 2018. Improved levels of heat/drought tolerance were identified in this selection using the detached shoot desiccation test.

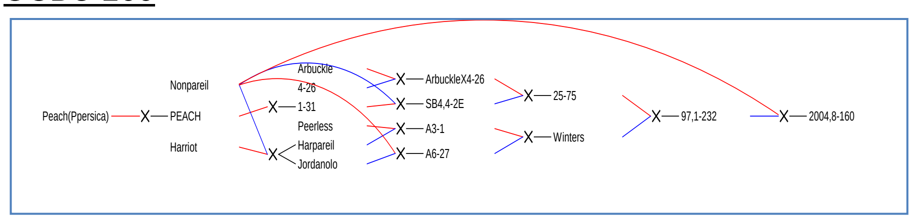
UCD18-20

The seed parent of this selection is F10D5-11, a selection from the early Prof. Kester/Dr. Jones UCD/USDA breeding collaboration, and which initially appeared to have self-compatibility. The pollen parent is the UC cultivar *Winters*, which, while genetically self-incompatible, demonstrates relatively high background levels of self-compatibility (which, unfortunately, has not been consistent from year to year). This selection has shown moderate levels of self-compatibility in some years but is more erratic in others and so is considered only partially self-compatible. Multi-year trials at WEO and the UC/Davis Pathology block have demonstrated compact tree size, large kernels, good productivity as well as good general pest resistance. The proportion doubles have been above 10% in some 2016 RVT plots. Double kernel levels higher than 10% were found all RVT's 2017. Bacterial spot symptoms were observed on UCD 18-20 at the Chico RVT in 2017. This selection produced some of the highest yields at the Chico State RVT in both 2016 and 2017 and at the Stanislaus and Madera RVT in 2017. It had one of the highest market values of all selections tested at the Stanislaus RVT based on 2-year cumulative yield and market value (**Table 2**).

UCD1-16

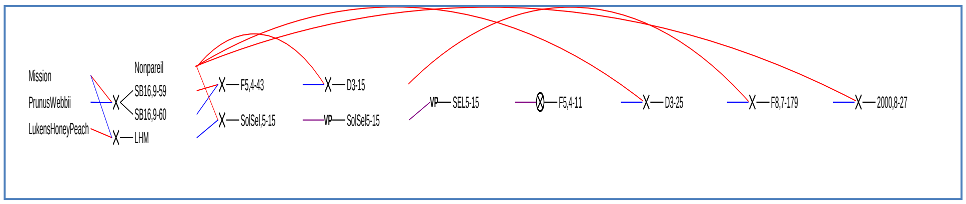
This selection was developed from a separate *P. fenzliana* lineage [Nonpareil X D3-19 {(Mission X *P. fenzliana*) X Solano}]. The selection is considered self-incompatible (*P. fenzliana* has not been a useful breeding source for self-compatibility). Kernel quality has been very good in multi-year WEO and Nickels Soils Lab testing though shell-seal is low and is comparable to Nonpareil. UCD1-16 has also demonstrated good general disease resistance in regional grower trials. Kernels pellicles also show a very desirable blonde-yellow color, comparable to Sonora. Trees are medium in size and productive. Double kernels levels higher than 8% were found that all RVT's in 2017. Improved levels of drought tolerance were identified in this selection using the detached shoot desiccation test. This selection also demonstrated some of the highest yields in Stanislaus RVT in 2017

UCD8-160



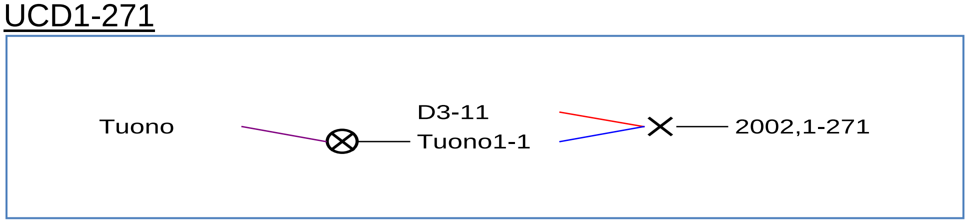
UCD8-160 has become one of the most promising of the new UCD breeding parents because of its combination of good kernel size and quality and consistently high self-compatibility plus self-pollination. It is a progeny of UCD2-232 which is also included in the RVT. Trees are more compact than *Nonpareil* yet are very productive, with production primarily on spurs. Multiyear testing at Nickels, WEO, and McFarland have demonstrated good general disease resistance despite the more compact structure of the trees. Very good self-sets were achieved in 2017 despite very poor bloom conditions. Greater than average hull rot at harvest was observed on UCD 8-160 at the Chico RVT in 2017 while evidence of leaf rust resistance was observed in a disease outbreak that year. Improved levels of drought tolerance were identified for this selection in multiyear dryland farm evaluations. This selection produced some of the highest yields at the Chico State RVT in both 2016 and 2017 and at the Stanislaus RVT in 2017. It had one of the highest market values of all selections tested at the Stanislaus RVT based on 2-year cumulative yield and market value (see **Table 2**).

UCD8-27



This selection represents a complex pedigree combining traits from both peach and *Prunus webbii*. High levels of self-compatibility have been recovered, as have good tree architecture and uniform crop distribution, primarily on spur bearing wood. [Earlier research has shown that the control of self-compatibility from *P webbii* is in the pistil while control from peach is in the pollen. By combining different genes and so different mechanisms for self-compatibility, we are attempting to improve both maximum performance and year-to-year consistency]. The tree is upright-spreading and approx. 20% smaller than Nonpareil. The paper shells give good crack out but poorer shell-seals. Kernels show good quality though twin embryos may occur. Navel Orangeworm damage was detected at 6 percent or more of the sample nuts in all regional variety trials in 2017. Double kernels at greater than 20% were detected in Butte and Madera RVT in 2017. Twig dieback from an undetermined cause was also observed on on low and interior shaded twigs of UCD 8-27 at the Chico RVT in 2017.

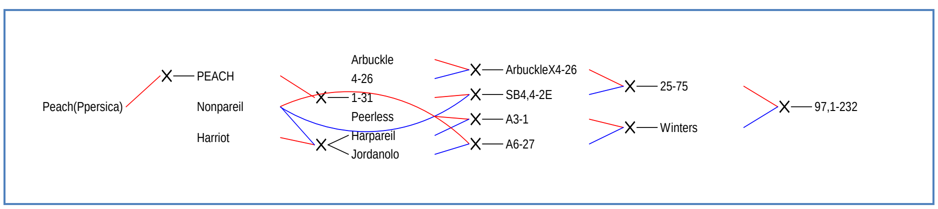
UCD1-271



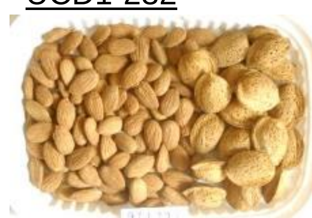
UCD1-271 utilizes the Italian cultivar *Tuono* as the source of self-compatibility, which has been heavily utilized by the earlier USDA Fresno breeding program as well as most Spanish and Italian breeding programs. While the *Tuono* has a very hard-shelled, irregularly shaped kernel, its commercially-adapted almond background allows self-compatibility to be more quickly transferred to locally adapted breeding lines. Our experience suggests it also contributes poorer kernel quality, with kernel creasing in progeny being a common problem. Most of the undesirable traits have been bred out in this selection while retaining good kernel quality and high self-compatibility. This selection is the result of targeting increased year-to-year production as well as self-compatibility consistency through recombination with more traditional breeding sources. Navel Orangeworm damage to levels greater than 10% was found in the Madera RVT 2017. Bacterial spot symptoms were observed on UCD 1-271 at the Chico RVT in 2017/18 with possible symptoms of Almond Leaf Scorch observed in 2018. An incidence of *Xanthomonas* infection on the fruit was confirmed by lab analysis in 2018 at the Madera RVT.

<u>UCD7-159</u>

This selection resulted from the cross of *Nonpareil* by 95,1-26 (USDA selection CP33 crossed with *Winters*) based on early data, which indicated that 95,1-26 had a novel source of self-compatibility. Recent test crossing at UCD has shown only moderate levels of self-compatibility in the 95,1-26 parent. Relatively high levels of self-compatibility have been identified in UCD7-159 suggesting that the 95,1-26 may still be a useful and unique source of self-compatibility but that expression is masked in the parent by its particular genetic background. Both tree and kernel show promising quality with good yields and low disease in earlier multiyear testing at WEO and Nickels plots.

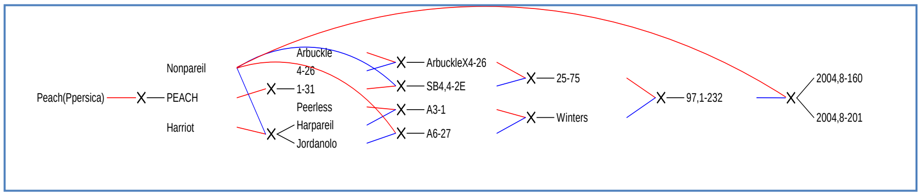


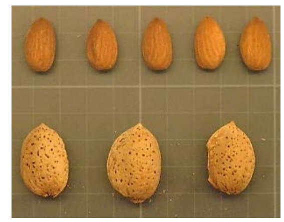
<u>UCD1-232</u>



UCD1-232 has been one of our most effective parents for the transfer of self-compatibility as well as good disease resistance. It combines desirable traits from peach as well as several heirloom California cultivars. Kernel qualities are not as good as the other advanced RVT selections yet within the range of commercially important current California cultivars. Multi-year testing has shown consistent levels of productivity, self-compatibility and disease resistance in this selection as well as in many breeding progenies using this selection is a parent. Possible tolerance to leaf rust was observed in 2016 RVT. [In addition to assessing commercial value of these accessions, the new multisite RVTs will allow more detailed evaluations of individual diseases in differing environments. This more extensive information will allow better assessment of these items as both potential cultivar releases as well as parents for future crosses]. Double kernels at 7% of sampled nuts were detected in the Madera RVT 2017. Twig dieback from an undetermined cause was observed on low and interior canopy shaded twigs of UCD UCD 1-232 at the Chico RVT in 2017. Greater than average hull rot at harvest was observed on this selection at the Chico RVT in 2017 while evidence of leaf rust resistance was observed in a disease outbreak that year. This selection produced some of the highest yields at the Chico State RVT in both 2016 and 2017.

<u>UCD8-201</u>





UCD8-201 is a sister line to UCD,8-160, described previously as one of our most promising sources of self-compatibility and kernel quality. Although kernels of this selection do not show the uniform high quality of UCD,8-160 (kernels are medium size and somewhat flat), the tree is particularly productive with a desirable upright spreading structure. Nuts are well-sealed. Branches show high density of spur production and have shown no significant disease with possible tolerance to leaf rust also observed in 2016 RVT, despite the consistently high crops. Twin embryos (multiple embryos with the same seed coat) have been higher than 10% in early RVT samples being slightly higher than is typical for Nonpareil. Double kernels were found that 18% or greater in all RVT's in 2017. Navel Orangeworm damage at 8% detected in the Madera RVT 2017. Greater than average hull rot at harvest was observed on this selection at the Chico RVT in 2017. Improved levels of drought tolerance were identified in this selection in multiyear dryland farm evaluations.   It also had one of the highest market values of all selections tested at the Stanislaus RVT based on 2-year cumulative yield and market value (see **Table 2**).