California Cling Peach Advisory Board
2019 Annual Report

Project Titles:	Development of New Cling Peach Varieties
Project Leaders:	Tom Gradziel
Cooperating Personnel:	S. Marchand, C. Crisosto, R. Bostock, T. DeJong and J. Adaskaveg
Location:	Dept. of Plant Sciences, Univ. of California at Davis

Summary Page

Breeding objectives for 2019 included:

a) Breed processing peach selections in the *Extra-Early* and *Early* season that need less labor during production and processing. Target harvest efficiency, including mechanical harvest, improved resistance to fruit brown-rot and flesh-bruising and improved processing quality.

b) Identify the most promising breeding lines as well as the most promising individuals within selected lines for more intensive testing as well as further crossing.

c) Generate 6,000 new seedling progeny trees targeting replacements for the *Extra-Early* and *Early* maturity periods as well as pre-Loadel maturity, the capacity for once-over harvest, fruit tolerant of mechanical harvest & transport, reduced requirements for pruning and thinning, and resistance to fruit brown-rot, mechanical bruising and inconsistent winter chilling. Develop hybridization methods to allow large-scale crossings under poor environments (low chilling, etc.) and poor weather (rain, wind, etc.) conditions.

Peach bloom season 2019 was relatively mild allowing the program to largely achieve the targeted goal of 6000 seed from breeding crosses. Good progeny seed recovery in 2019 crosses was further improved by the availability of new crossing blocks in Davis and Winters. Over 3000 of resulting seed have now been germinated and/or planted in greenhouses for the initial round of selection. Breeding parents were selected to target productive and high-quality processing peaches maturing in the *Extra-Early* to *Early* processing season, improved brown rot resistance, capacity for once-over-harvest and consistent bloom/crop under conditions of changing winter chill. Approximately 40% of crosses also targeted anticipated future varietal requirements for reduced labor inputs. Particular focus was given to traits facilitating mechanization of harvest, thinning and pruning.

Over 20,000 progeny trees were evaluated in 2019, primarily through visual inspection during weekly patrols in the bloom and fruit ripening season. Of these, 28 were selected for further evaluation either as candidate selections or as parents for further, directed crossing. The 2012 to 2016 progeny blocks represent the most advanced generation of breeding populations incorporating traits from almond and wild relatives. Several of these breeding populations involve the recombination of improved brown rot resistance and fruit quality from several diverse sources with the goal of further improving field performance as well as stability under changing environments. Over 600 selections were advanced to more detailed trait characterization (phenotyping) as well as genotyping to investigate possible useful molecular markers. All molecular genotyping was done by collaborators as part of the final year of the RosBreed project. Beginning in 2020 we will be doing molecular analysis in-house in our dedicated molecular lab at UC Davis. To date, molecular markers have proven useful in providing a better understanding of the trait and its inheritance, as well as the differences between different germplasm sources. However, the complexity of the traits as well as different genetic sources still require thorough field validation for traits as basic as fruit size. New evaluation plots have also been established in Davis and Wolfskill to allow research including orchard modeling studies focusing on orchard mechanization.

Introduction.

The needs for the California processing peach industry differ from the production of fresh market fruit since the lower returns for processed fruit require greater production efficiency and crop consistency over an expected extended orchard life of 20 years or more. Achieving these goals requires the identification and incorporation of new traits for reducing labor inputs while increasing productivity and processing quality. A problem encountered early in the variety development program was the very limited germplasm diversity available to solve new problems. Consequently, a major effort has been expended towards bringing in new and diverse germplasm and so new traits from wild peach and almond relatives (Figure 1, as detailed in earlier annual reports). While the transfer of desired traits from wild to California adapted selections has taken several decades, we now have an unparalleled breeding germplasm transferred into commercial processing peach background, thus providing novel opportunities to meet emerging industry needs. We have also been successful in leveraging the resulting large and diverse breeding populations to obtain supplemental funding (USDA, SCRI, etc.) for the more costly and technically demanding analysis required to develop molecular markers for important traits. In the 2009-2012 SCRI multi-state RosBreed (www.rosbreed.org) project for developing molecular markers to improve fruit crop breeding efficiency, the largest proportion of peach selections analyzed were from the UCD processing peach program (350 genotypes) since we had the required fruiting population sizes and genetic diversity already established in mature field plantings. In the subsequent 4-year RosBreed-2 molecular-marker development project, the number of UCD peach selections analyzed was increased to over 1,700 individuals. With the end of this program in 2019, we are currently compiling the molecular and field trait data and beginning the tedious process of searching for association between desired traits and RosBreed molecular markers. If associations are consistent, those molecular markers could then be used as accurate predictors of the presence of the trait even at the seedling stage, thus making the breeding program more rapid and efficient.

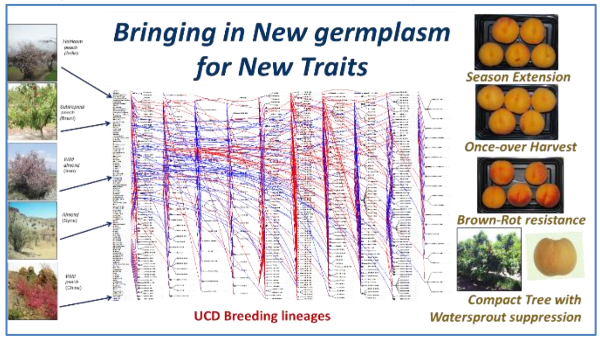

Figure 1. Diverse germplasm incorporated into advanced breeding lines with examples of targeted traits.

Table 1. Breeding targets an actual seed/seedling recovery for the past 5 years

Year	Target	Planted
2015	3000	3211
2016	5000	3700
2017	8000	3027
2018	9000	3234
2019	6000	4859

Beginning in 2018 and continuing into 2019, new breeding blocks were established at Davis and the Wolfskill Experimental Orchards (WEO). These plantings supplement aging breeding blocks as well as to provide alternative crossing environments when confronted with local inclement weather patterns such as frost, localized low-chilling, etc. Over 5000 seed was recovered from breeding crosses in 2019, largely attaining are desired target (Table 1). Over 36,000 controlled hybridizations, among 22 different parental combinations were made in 2019 with the benefit of favorable weather conditions both during and after bloom. To date, over 4800 seed have been planted to greenhouses for the initial stages of screening for vigor and desirable plant characteristics. We are also modernizing our molecular diagnostic lab for molecular marker assessment since, with the end of RosBreed, we no longer outsource as much of that work to collaborators. During this breeding period, the processing peach breeding program has been successful in developing and releasing commercially valuable processing peach varieties (Figure 2 as detailed in earlier annual reports). The recent and continuing breeding focus is on the *Extra-Early* and *Early* harvest seasons and has resulted in the release of the varieties *Kader* and *Vilmos* with additional advanced selections being considered for future release (as described in the Regional Testing annual report). Two 2019 publications summarizing these releases are included in the appendix. While much of the presented information is from earlier annual reports, these papers provide a more comprehensive summarization as well as field updates.

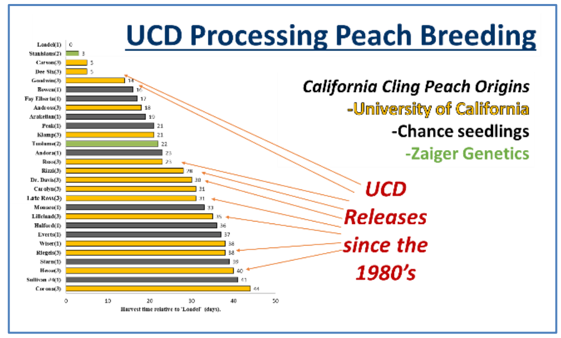

Figure 2. Varieties developed at UCD.

While the majority of our 2019 breeding crosses continued to target improved varieties in the *Extra-Early* and *Early* maturity seasons, approximately 40% of crosses also moved to address anticipated future needs, particularly the development of varieties requiring reduced labor inputs. Strategies and progress of this effort are summarized below.

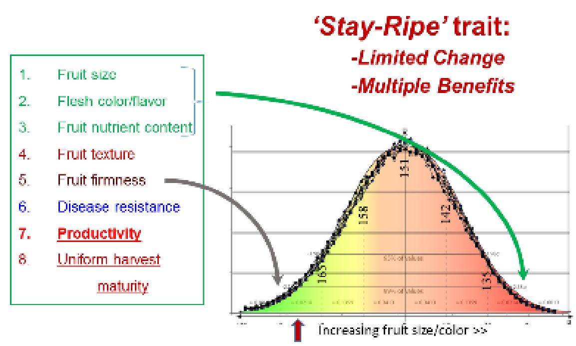

Figure 3. By allowing early tree-ripe fruit to retain processing quality until the final fruit achieves tree-ripe improves quality, yield, and fruit grade.

Breeding for Reduced Labor Inputs.

In response to the dramatically increasing costs of labor, the UCD Processing Peach Breeding program has been pursuing genetic options allowing labor reductions. Future orchard management strategies will need to move towards much greater labor efficiency and/or mechanization. In most orchard scenarios, traits facilitating mechanization should also allow for greater manual labor efficiency, either as an interim practice until full mechanization is achieved, or as a more integrated orchard management strategy. For example, uniform harvest, while being an essential trait for any mechanized harvest scheme would also improve the efficiency of once-over hand-harvest. Thus, the UCD processing peach variety development program is pursuing the often-novel traits required for mechanization with the expectation that these traits would also allow greater efficiency with the more limited availability of hand labor in the near future. The main orchard management practices targeted are harvest, pruning, and flower thinning.

Table 2. The maintenance of processing quality for 2 to 4 weeks after tree-ripe of UCD selections *Vilmos* and *Compact-2* relative to standard cultivars.

		Fruit Firmness in pounds {STD}		
	Ripe Date	Tree-Ripe	2 weeks after Tree-ripe	4 weeks after Tree-ripe
Andross	15-Jul-15	5.8 {1.5}	2.4 {1.3}	< 1.0
Vilmos	16-Jul-15	6.4 {1.2}	5.4 {1.8}	4.5 {2.6}
Cmpt.2	8-Jul-15	7.1 {1.4}	5.7 {1.6}	4.8 {2.9}
Klampt	18-Jul-15	6.3 {1.8}	< 1.0	< 1.0

1. Harvest.

Mechanized harvest would require capacity for once-over harvest and firm, brown-rot and bruising resistant fruit. Progress in improving brown rot and bruising resistance have been summarized in previous reports which demonstrate that selection strategies within our enriched breeding germplasm continues to be effective for improving these traits. This report will focus on efforts towards achieving once-over harvest.

Once-over-harvest.

The development of a peach demonstrating uniform fruit-ripening is particularly challenging because individual fruit development is driven by local carbohydrate availability (i.e. sun-exposed leaves) and local heat units. Consequently, interior shaded fruit or fruit in the north sides of the trees will inherently lag behind fruit developing with a southern exposure. An additional problem is the protracted flowering observed after insufficient winter chilling, which can result in differences in fruit maturity time of a week or more. Previous reports have also demonstrated breeding program effectiveness in selecting for varieties (such as the recently released *Kader* and *Vilmos* varieties) which are more tolerant to these chilling vagaries. To achieve the capacity for once-over harvest, we have aggressively bred for peaches which ripen normally but then can remain on the tree without significant loss in processing quality for 2 weeks or more. While both *Kader* and *Vilmos* demonstrate improved performance in this '*stay-ripe*' trait (Table 2), new breeding germplasm offers opportunities for even greater advancement in this area.

Figure 4. Compact-3 at tree ripe, and harvested 2 and 3 weeks after tree-ripe.

***Stay-ripe* trait.**

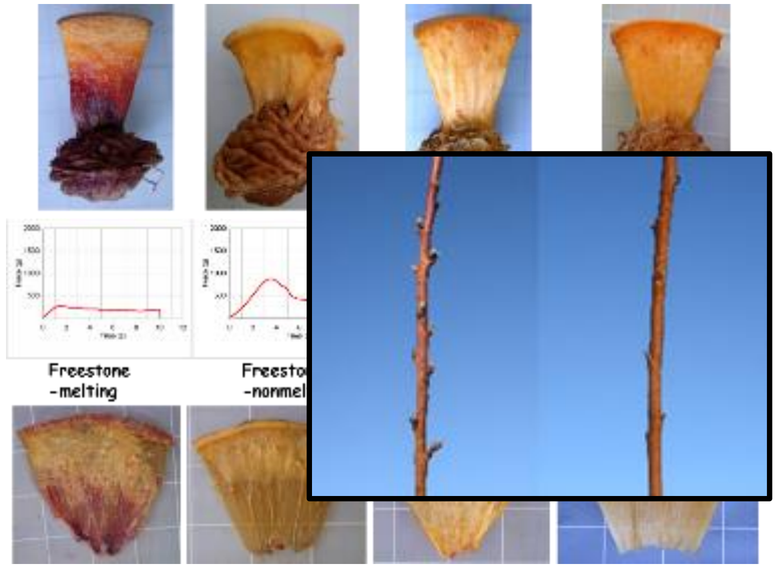

Figure 6. Sectioned fruit showing differences in internal flesh architecture. Grafts show fruit firmness when proved is punctured from the exterior to the pit, thus providing a representation of texture or density of the fruit from the skin (left) to the pit (right).

Fresh market peach breeding efforts to achieve a more uniform harvest have focused on genes which affect fruit ripening, as in the variety *Autumn Flame*. Unfortunately, these genes delay the ripening process to the point that in some years, a full tree-ripe state is not achieved. Our approach has been to allow normal ripening to the tree-ripe stage and then suppress post-ripening fruit deterioration. With this *'stay-ripe'* trait, the earliest fruit that ripen can maintain processing quality for a week or more allowing lagging fruit to also achieve full-ripe quality. While allowing a more efficient once-over harvest (either manually or mechanically) this approach also increases both the final yield and quality of the harvested fruit because the proportion of previously unmarketable under-ripe and overripe fruit are now minimized, while the extra-field time provides the opportunity for all fruit to achieve full size (maximum yield) and quality (maximum sugar, minimum rejects) [Figure 3]. Table 3 shows a comparison of the traditional varieties *Klampt* and *Andross* with the recently released *Vilmos* variety, demonstrating *Vilmos'* capacity to retain fruit firmness and quality for up to 2 weeks after initial tree-ripe. *Vilmos* contains exotic germplasm from wild species that contributes to both the *stay-ripe* trait as well as improved fruit size. Even better performance is observed in the UCD advanced selection *Compact-2* which combines both compact tree structure (see next section) with the *stay-ripe* trait, both of which appear to have originated as bud-sport type mutations. Figure 4 shows harvest quality of a sister line, *Compact-3*, at tree ripe and 2 and 3 weeks after tree ripe. A 3rd source of the *stay-ripe* trait is of genetically unique South African germplasm which was the source for the *Early-6* advanced selection now undergoing the final stages of regional grower trials (see Regional Testing annual report). *Early-6* also incorporates a *'highlighter'* gene which suppresses all red fruit-pigmentation, even in overripe fruit. The breeding program is now attempting to incorporate

Figure 5. Halved peach fruit showing that most flesh is composed of compact strands radiating from the pit with a lesser number of vascular flesh strands originating from the stem area and developing primarily near the fruit skin. The large pit feeder-bundles can be seen in the internal flesh channeling of the fruit at the right and partially within the pit channels of the fruit at left.

stay-ripe genes from different genetic sources in order to improve performance and environmental stability. Parallel efforts are also pursuing an understanding of the mechanism for this trait. Cross-sectional fruit-sections for standard freestone-melting and clingstone-nonmelting are shown in Figure 5. Also shown is a section from an almond-derived *stay-ripe* breeding selection as well as an independent gene/trait conferring the previously unknown combination of freestone-nonmelting. In the original almond-derived freestone-nonmelting selection *UCD 1-42*, the fruit is air-free and both structurally and genetically non-melting (as detailed in earlier annual reports), though fruit tend to soften and deteriorate quicker than standard non-melting clingstones. In addition, while the inheritance of the *stay-ripe* trait is complex, we have been able to move it into different clingstone peach backgrounds but not into freestone backgrounds. Developmental studies suggest that the *stay-ripe* trait is associated with a prolonged maintenance of flesh vascular strands. As shown in Figure 6, virtually all of the fruit flesh is basically composed of 2 types of such strands; the first radiating out from the pit and the 2nd, more peripheral to the fruit, radiating out from the stem area. In clingstone, nonmelting fruit, the connections between strands and between strands in the large feeder-bundles in the pit channels are more resistant to melting (that is, cell separation). It is hypothesized that the *stay-ripe* trait maintains these connections between outer and inner flesh strands in the core fruit feeder-bundles located at the stem and in the pit-channels. The continuity of vascular strands allows the continued maintenance and so survival of fruit flesh cells. Post-ripening deterioration, then, is thus more a programmed tissue breakdown then a chaotic loss of function. This hypothesis would also explain why it is more difficult to incorporate stay-ripe into freestone-melting types. In these fresh market types, the melting results from breakdown between strands while the free-stone results from breakdown between the major feeder bundles in the pit channels and the major flesh-determining strand r s radiating from these channels (As in Figure 6). In order to test this hypothesis, fruit anatomy studies, particularly of the vascular strands, are planted in 2020 examining both fruit at tree-ripe and at various stages after tree-ripe. If a plant developmental anatomy characteristic is causative and so closely associated with this trait, that characteristic could then be used as a more accurate selection method for the *stay-ripe* trait in the future.

Figure 7. Shoots of the compact growth type (left) compared with normal (right) showing the reduction in internode length and so total shoot length.

Table 3. Shoot characteristics for the 'compact' trait relative to standard shoot growth.

	Standard	Compact
Shoot length (in.)	46	24
Number of nodes	31	28
Internode length (in.)	0.9	0.6

2. Pruning.

Mechanical pruning is a particular challenge for peach because both tree size and current-year shoot growth can become unmanageably large. Because flowers and so fruit form only in the

Figure 8. High density Trellis-trees in a test plot and Salida, CA.

Figure 9. Compact selection trained to a trellis at WEO

Figure 10. High-density perpendicular orchards of Compact-3 (top) and Monaco (bottom) after summer pruning.

axillary nodes of the previous seasons growth, peach production requires a vicious cycle of promoting extensive new shoot growth that then has to be pruned back to encourage the next season's shoot growth. One promising approach to peach mechanization was to incorporate the 'compact' trait into new varieties. Discovered as a budsport mutation in our breeding program in the 1990's, this trait is controlled by a single semi-dominant gene and result in the reduction of the leaf-to-leaf internode length by ½ to 1/3 (Figure 7, Table 3). The total number of nodes remains almost the same for both *compact* and standard types. Consequently, the final shoot length is from ½ to 1/3 shorter than control (Table 3). Despite the shorter length, *compact* shoot have a similar number of internodes and so produce a similar number of flowers and so fruit, but without the need for extensive new shoot growth. [The shorter internode length can result in dense, shaded foliage that can suppress normal axillary shoot pushing, resulting in sections of blind-wood]. In addition to a smaller shoot size, the *compact* types are less likely to continue shoot growth beyond the preformed nodes present in the overwintering buds. The resulting small tree stature and limited new shoot growth make this trait particularly useful for high-density orchards including training systems such as perpendicular-V on trellis (Figure 8). Such a high density, highly managed trees showed good production in a Salida grower test plot yet with virtually no need for summer pruning (Figure 10).

Figure 11. Horizontal shoots of trellis-trained Compact selection showing good bearing wood renewal without excessive growth and, in particular, without excessive vertical waterspouts.

Additional evaluation blocks of *compact* selections have been established in UCD plots at Davis and Wolfskill Experimental Orchard (WEO) in Winters California. The WEO plot has been trained to a trellis system to evaluate the resulting shoot growth response for different compact selections (Figure 9). As with the perpendicular-V high-density plantings, shoot growth on even strongly lateral branches was so well contained that trellis or other intensive training systems seemed unnecessary (Figure 11). Of particular importance, was a suppression of aggressive perpendicular suckers that have proven the bane of many intensive peach training systems (Figure 11).

Figure 14. Hedging *Compact-3* into a fruiting wall type system.

Figure 13. Hedged trees of Compact-3 at fruiting.

Figure 12. Pillar tree architecture for clingstone peach.

The Davis evaluation plot was set up to evaluate hedging as a training system (Figure 12) using the *Compact-3* selection shown in Figure 4 (the *stay-ripe* trait has now been incorporated into most advanced *compact* selections). The consistent replacement of bearing-would without excessively vigorous current-season shoot growth including suckers/waterspouts resulted in a readily managed system with good yield potential (Figure 13). Because of some blind-wood development as well as some interior shading (in future plantings I would trained to a bout a 4 foot with rather than the 7-8 foot used here), yields were not as high as traditional commercial operations but this might be compensated by dramatic reductions in labor.

We are also experimenting with other approaches for tree size/shape control to facilitate mechanical harvesting. These include additional size-controlling rootstocks and we are currently evaluating affect on peach of some of our peach and plum hybrids developed in the almond breeding program utilizing some of the size control predictors developed in Ted DeJong's earlier rootstock programs. We have also been able to recover a fairly highly heritable pillar-type tree architecture (Figure 14) that could facilitate mechanization and peach much of these types have been utilized in apple. While the genetic control remains uncertain, the trait does sufficiently heritable that it can be recovered in a large number of progeny. Because its origin was a relatively recent hybridization with the wild peach, Prunus davidiana, we are still in the process of bringing food quality and productivity up to California standards.

3. Thinning.

All UCD breeding evaluation blocks are currently mechanically hedged and mechanically thinned (Figure 15) to identify promising tree structures and bearing habits while at the same time, minimizing labor charges. The flowering/fruiting wall of hedged compact trees such as those in Figure 13 have proven particularly amenable to this type of mechanical thinning. Because hedging occurs during the winter prior to flowering, we use our hedging cuts to cut back no lateral shoots to reduce the number of flower buds while still maintaining sufficient flower density to compensate for spring time frost, etc. Just following bloom, (at the beginning of petal

Figure 15. Using the Darwin set up the mechanically thin a peach flowering wall at the UCD evaluation plots.

drop) we use the Darwin thinner to further reduce flower density as needed. This approach still leaves too many fruit in the interior of canopy, particularly within the row between adjacent trees. However, because of the compacts inherently lower flower density in inherently greater capacity to size congregated fruit, most of these fruit are still able to achieve commercial size. Future test plantings will have a narrower width to further reduce previously unmanageable interior fruit. Such a narrower fruiting wall would conceivably be more amenable to more basic robotic flower thinning strategies currently being tested in apple and pear. Both black, as well as a new black been developed at WEO are also being made available for researchers studying orchard modeling within the Plant Sciences Department and mechanical harvest for researchers in the Agricultural Engineering Department.

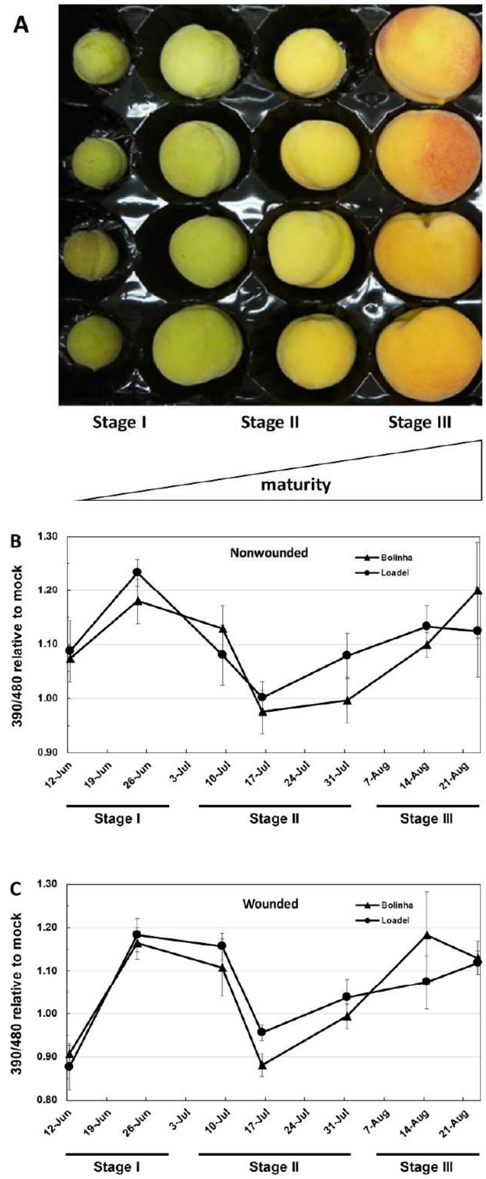

Figure 16. Redox of aqueous diffusates from peach fruit surfaces of different developmental stages as perceived by the bioreporter. (A) Representative fruit stages of peaches of increasing maturity (cv. Loadel). (B) relative values for diffusates from the surfaces of nonwounded Bolinha and Loadel peach fruit. (C) relative values for diffusates collected from wounds in peach fruit surfaces, cvs. Bolinha and Loadel. Each value is the mean ± SE of four replicate samples.

A rapid assay for evaluating resistance to brown rot.

Flower blights and subsequent fruit brown-rot are major sources of crop loss in peach. The long-term collaboration between the UCD Processing Peach Breeding Program aand The Plant Pathology Diagnostic Lab of Rick Bostock (initiated by his early processing peach funded fruit brown rot resistance screening program) has recently developed a novel bio-reporter approach to disease resistance screening. Because our analysis of promising resistance sources in the diverse UCD interspecies breeding germplasm demonstrated that many of the more promising resistance mechanisms altered the redox chemical environment of the plant-microbial interface, Rick Bostock's lab was able to develop a rapid, noninvasive assay that uses a bacterial bioreporter that responds to ROS and redox-active environments (see the Liu, Yaghmour, Lee, Gradziel, Leveau, and Bostock 2019 Phytopathology paper in in the recent literature section at the end of this report). The redox environment of the phytobiome, i.e. the plant-microbial interface, can strongly influence the outcome of the interaction between microbial pathogens and their host. To compare microenvironments perceived by microbes during their initial encounter of the plant surface a reduction-oxidation sensitive variant of green fluorescent protein (roGFP2), responsive to changes in intracellular levels of reduced and oxidized glutathione, was expressed in epiphytic bacterium. Aqueous washes of peach flower petals from young blossoms created a lower redox state in the bioreporter than washes from fully mature blossoms. The bioreporter also detected differences in surface washes from peach fruit at different stages of maturity and between wounded and nonwounded sites. The reporter rapidly assesses differences in redox microenvironments and provides a noninvasive tool that may complement traditional analyses of cell extracts. This assay promises to improve selection efficiency for blossom and fruit microenvironments associated with improved disease resistance in both laboratory and field conditions.

Recent Relevant Publications

2019 Gradziel, T. and S. Marchand. 2019. 'Kader' Peach: a Processing Clingstone Peach with Improved Harvest Quality and Disease Resistance, Ripening in the 'Dixon' Maturity Season. HORTSCIENCE 54(4):754–757. 2019. https://doi.org/10.21273/HORTSCI13708-18

2019 Gradziel T, B. Lampinen and J.E. Preece. (2019). Propagation from Basal Epicormic Meristems Remediates an Aging-Related Disorder in Almond Clones. *Horticulturae* **2019**, *5*(2), 28; https://doi.org/10.3390/horticulturae5020028

2019 Gradziel, Thomas M. and Jonathan Fresnedo-Ramírez. (2019). Noninfectious Bud-failure As a Model for Studying Age Related Genetic Disorders in Long-Lived Perennial Plants. Journal of the American Pomological Society 73(4): 240-253 2019

2019 Liu, Ting-Hang, Mohammad A. Yaghmour, Miin-Huey Lee, Thomas M. Gradziel, Johan Leveau, and Richard M. Bostock. 2019. A roGFP2-based bacterial bioreporter for redox sensing of plant surfaces. Phytopathology September 4, 2019. https://doi.org/10.1094/PHYTO-07-19-0237-R

2019 Gradziel, T., and S. Marchand. 2019. 'Vilmos' Peach: A Processing Clingstone Peach Expressing a Novel 'Stay-Ripe' Trait With Improved Harvest Quality, Ripening In The 'Andross' Maturity Season. HORTSCIENCE 54: 2078-2080. 2019. https://doi.org/10.21273/HORTSCI14291-19.

2019 Gradziel, T. M., and. B. Lampinen. 2019. 'Kester' Almond: A Pollenizer for the Late 'Nonpareil' Bloom with High Yield and Kernel Quality. HORTSCIENCE 54(n):1–2. 2019. Https://doi.org/10.21273/HORTSCI14398-19

Appendix. Original PDFs of these articles can be downloaded for free using the DOI numbers provided in the publication reference above.

HortScience 54(4):754–757. 2019. https://doi.org/10.21273/HORTSCI13708-18

‘Kader’ Peach: A Processing Clingstone Peach with Improved Harvest Quality and Disease Resistance, Ripening in the ‘Dixon’ Maturity Season

Thomas Gradziel[1] and Sabrina Marchand
Department of Plant Sciences, One Shields Avenue, University of California, Davis, CA 95616

Additional index words. breeding, fruit, genetic-improvement, fruit brown-rot disease, uniform-harvest

‘Kader’ peach [*Prunus persica* (L.) Batsch] produces a clingstone, nonmelting fruit suitable for processing or fresh market. Evaluated as selection ‘90,9-116’, it was derived from a cross between breeding selection ‘R1-1’ and the University of California, Davis, cultivar Ross, which had ‘Dixon’, ‘Elberta’, and PI 292557 in its lineage. Ripening time occurs during the commercially important ‘Dixon’ period, ≈6 d before that of ‘Fay Elberta’. During long-term commercial evaluations, fruit demonstrated very good harvest, postharvest, and processing quality, with low proportions of the undesirable endocarp or pit splitting and the associated red anthocyanin staining of fruit flesh, as occurs in many cultivars of this maturity. Fruit possess good firmness and color very similar to that of the commercially important cultivar Andross. Trees have proven to be consistently productive during more than 12 years of continuous commercial evaluation in environments with 700 h or more of winter chilling. Tree form is semi-upright, with vigor and branch architecture similar to ‘Andross’. Flowers are pink, showy, and large. Leaves are medium-to-dark green, with globose leaf glands.

Origin

The University of California at Davis (UCD) has maintained a processing peach breeding program since the 1980s with the support of the California cling peach growers and processors. The primary objective of the breeding program was to develop replacements for the early maturity season cultivars Dixon and Andross. ‘Dixon’ was introduced in 1956, and it was one of the first extra-early maturity season cultivars that could consistently achieve commercially profitable yields when thinned to achieve desired fruit sizes of 60 mm or larger. Fruit flesh is a desirable yellow-gold and it possesses good fresh and processed eating quality, but the fruit pit cavity often develops a pink to red color from the formation of red anthocyanins. The anthocyanins oxidize to brown when heat-processed, staining both the processed fruit and syrup. The ‘Dixon’ fruit endocarp or stone is also more susceptible to breakage, resulting in undesirable pit fragments in processed fruit. Because of these problems, processors discontinued ‘Dixon’ fruit purchases. Therefore, this cultivar is no longer

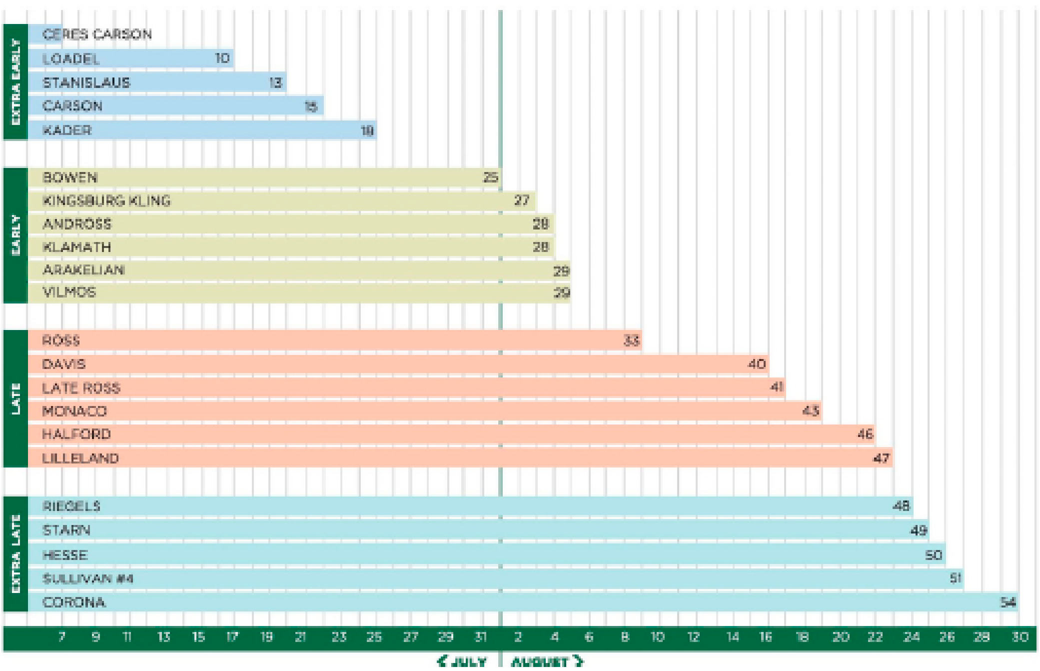

Fig. 1. Fruit maturity of ‘Kader’ relative to commercial canning clingstone peaches in California. In commercial production, the cultivar Dixon ripened ≈1 week after ‘Carson’ and 1 week before ‘Andross’. The production gap resulting from its removal from commercial planting is commonly known as the Dixon gap. ‘Kingsburg-Cling’ is an early ripening mutation of University of California at Davis cultivar Dr. Davis currently being test-planted as an alternative to cultivar Andross (California Canning Peach Association, 2017).

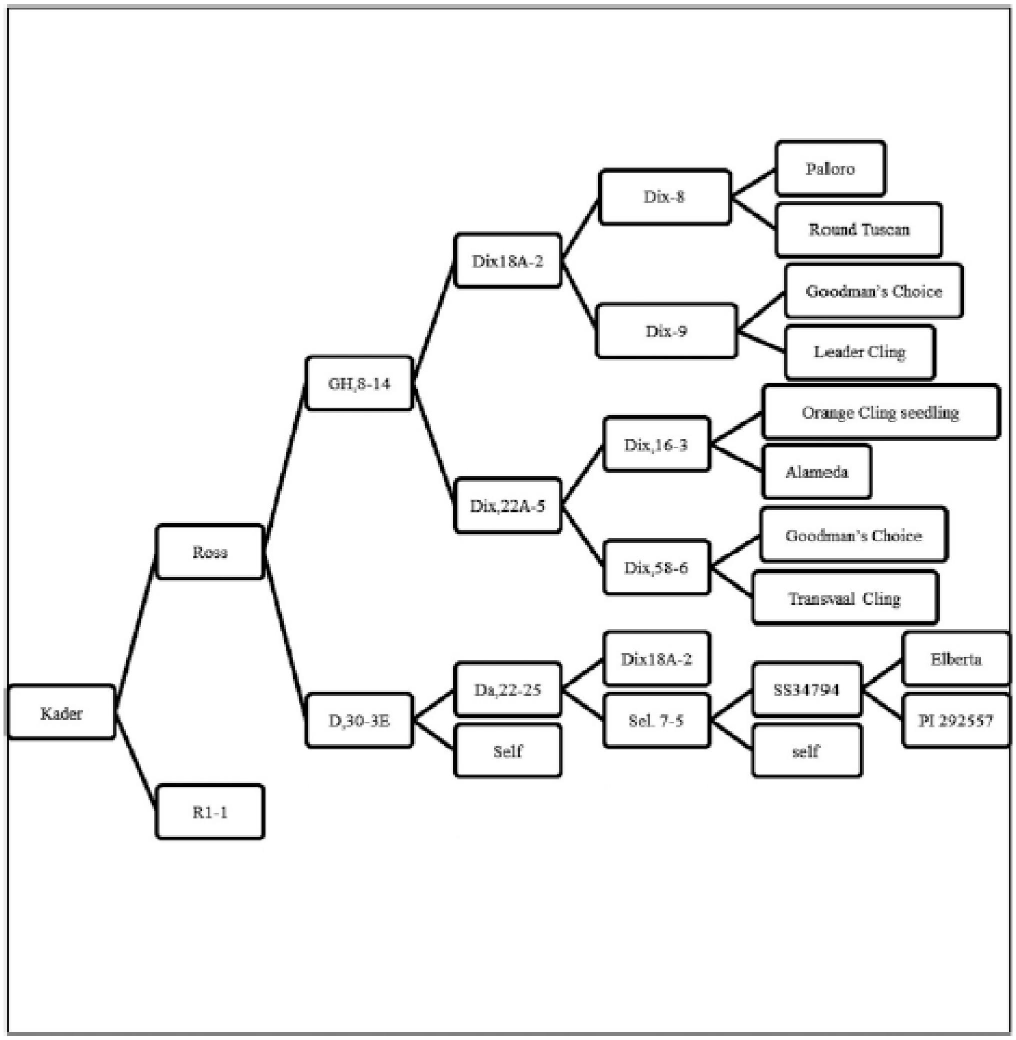

Fig. 2. Pedigree of the 'Kader' peach. Seed parent is presented at the top. The origin of the pollen parent R,1-1 is unknown. The designation PI 292557 is from early breeder records and does not refer to the ARS GRIN database.

commercially planted, and no replacement cultivar currently exists (Fig. 1). The cultivar Carson has remained the only commercially successful processing peach harvested during the resulting 'Dixon' gap, followed by the 'Andross' harvest season. 'Andross' was developed as a source of fruit for processors during the early maturity season following 'Dixon' production. 'Andross' originated from a cross with 'Dixon' as a grandparent and was introduced in 1964. 'Andross' has become the most heavily planted cultivar during the early maturity season because of its proven potential to produce abundant firm fruit with good commercial size. 'Bowen', the only remaining established cultivar ripening during this season (Fig. 1), also has 'Dixon' as a grandparent, but it has never achieved high plantings due to inferior fruit quality and yields. Pedigree analysis has documented the extensive use of 'Dixon' as well as a sibling selection designated 'Dixon #2' during cultivar development efforts before the 1980s (Gradziel et al., 1993). With the release of the UCD cultivars Dr. Davis and Ross in the 1980s, new, yet highly adapted germplasm derived from the germplasm identified in breeder records as 'PI292557' and the freestone cultivar Elberta were made available for continued genetic improvement. Because of their high fruit quality and yield potential, Dr. Davis and Ross have become the most extensively planted processing peach cultivars in California. 'Kader' is a product of a breeding effort to combine desirable traits of 'Andross' and 'Ross' during a controlled cross between

Received for publication 31 Oct. 2018. Accepted for publication 5 Jan. 2019.
[1]Corresponding author. E-mail: tmgradziel@ucdavis.edu.

Fig. 3. Fruit and stone morphology of 'Kader' peach (grid = 1 cm).

University of California processing peach breeding line 'R,1-1' as the male (pollen) parent and the University of California processing peach cultivar Ross as the female (seed) parent (Fig. 2). Originally designated as seedling '90,9-116', it was selected based on its good fruit and tree qualities, its freedom from red staining of the pit, low frequency of pit fragments in processed flesh, and desirable ripening time that occurs 10 d before that of the cultivar Andross. Regional evaluation plots for '90,9-116' were established in 2001 at Winters, CA and Davis, CA in the Sacramento Valley and at the Kearney Agricultural Center in Parlier, CA in the San Joaquin Valley, and in 2004 at multiple grower evaluation plots in the Sacramento and San Joaquin Valleys under the designation 'UCD-Extra-Early #1'. Based on its positive evaluations, selection '90,9-116' has been patented and released as the processing peach cultivar Kader.

The name 'Kader' was chosen to acknowledge the extensive contributions to peach harvest and postharvest knowledge by Professor Adel Kader during his career in the Department of Pomology, and subsequently in the Department of Plant Sciences at UCD.

Description

'Kader' peach [*Prunus persica* (L.) Batsch] ripens during the commercially important 'Dixon' period, between the periods of 'Carson' and 'Andross'. In addition to its desirable ripening period, the processing clingstone fruit have a low incidence of undesirable pit-splitting and red anthocyanin staining of pit cavities, as occurs in the Dixon and Andross cultivars. Fruit are large, slightly ovate to round, and have a slight fruit tip, although they are free from the elongated tip found on several clingstone peach cultivars following mild winter and warm spring weather (Fig. 3). Flesh is bright yellow to yellow-gold, with improved resistance to fruit brown rot (Monilinia fructicola) in field and controlled laboratory conditions. Fruit skin is slightly less pubescent than that of 'Andross', with a more uniform golden-yellow color. Pit has a medium size and has remained free from the red staining and extensive pit fragmentation of 'Dixon' and 'Andross', even in environments promoting these conditions. Tree is semi-upright, with vigor similar to that of 'Andross'. Branch architecture is similar to that of 'Andross', although often with a denser canopy. Flowers are pink, showy, and large; two flowers per node are commonly present. Leaves are medium-to-dark green with globose leaf glands, similar to those of 'Andross'.

Table 1. Performance of 'Kader' clingstone processing peach compared with the California cultivars Carson and Andross. Fruit were from the University of California at Davis Wolfskill Experimental Orchards in Winters, CA as part of the 3-year RosBreed peach genome project (Gasic et al., 2011).

	Carson	Kader	Andross
Raw fruit size (g FW)[z]	219.5 a	332.7 b	332.2 b
Raw fruit firmness (kg)[y]	5.2 a	6.9 b	7.5 b
Processed flesh color 'a' value[x]	5.0 a	7.0 b	6.9 b
Processed flesh color 'b' value[x]	50.8 b	45.0 a	45.9 a
Processed flesh color 'L' value[x]	71.5 a	77.2 a	78.1 a
Flesh browning[x]	0.04 a	0.03 a	0.40 b
PPO activity (mL Abs/min)[w]	156 a	178 a	383 b
Resistance to Monilinia fruit rot[v]	9.5 b	5.2 a	9.39 b
Proportion with red pit staining	0 a	0 a	0.7 b

[z]Mean separation performed within each row by Duncan's multiple range test. $P = 0.05$ from a sample size of 50 fruit (unless otherwise indicated) randomly harvested from the 12th leaf of trees thinned to achieve a commercial size of 60 cm or larger.

[y]Fruit firmness was measured with a Magness-Taylor firmness tester using an 8-mm tip with the fruit epidermis removed.

[x]CIELAB 1976 L*a*b* color space. Flesh browning was measured as the proportion 'L' value decrease 12 h after cutting, as described by Techakanon et al. (2016).

[w]Polyphenol oxidase (PPO) values are from 10 fruit samples per genotype, as described by Techakanon et al. (2016).

[v]Disease resistance values are from 20 fruit samples replicated over 3 consecutive years, as described by Gradziel (1994).

Performance

Trees were evaluated from 2001 to 2016 under standard commercial conditions in the Sacramento and San Joaquin valleys. Trees produced a medium to high crop, larger than that of 'Carson' and comparable to that of 'Andross' and thus needing less thinning following a high-chill winter. 'Kader' bloom was uniform and abundant when chilling hours were above a 700 h using the Utah model, as occurred at all Central Valley (including Sacramento and San Joaquin Valley) test sites during all years. Bloom time at Central Valley commercial production sites occurred during midseason in relation to other commercial cling peach cultivars, similar to 'Carson' and 'Andross'. 'Kader' fruit were fully clingstone and nonmelting. Fully ripe fruit, as determined by a lack of visible green pigmentation on the fruit epidermis, had an orange-yellow primary ground color with 10% to 50% red blush. Fruit skin had a fine, short, and netted pubescence, with no observed tendency to crack. Some split pits occur during low crop years, although at much lower rates than that of either 'Dixon' or 'Andross'. Fruit size and flesh (mesocarp) firmness demonstrated a significant improvement compared to the Carson and Dixon cultivars and were comparable to the Andross cultivar (Table 1). Fruit mass was similar to that of 'Andross' when thinned using recommendations developed for the Andross cultivar (California Canning Peach Association, 2017) to achieve commercial fruit diameters of 60 mm or larger. 'Kader' fruit were fully acceptable to California processors during the 12-year commercial evaluation period. Fruit shape and quality were similar to those of the Andross cultivar (Fig. 3), although with a reduced level of polyphenol oxidase activity and associated flesh browning, but with improved fruit brown rot resistance as caused by *Monilinia fructicola* (Table 1). Fruit brown rot 3-year average disease severity ratings (measured as the product of the lesion incidence by average lesion diameter 48 h after controlled inoculation) for 'Kader' were considerably lower than those of cultivar standards Carson and Andross (5.2 vs. 9.5 and 9.4, respectively). The fruit stem cavity of 'Kader' was found to be similar to both the Dixon and Andross cultivars, with a consistently broad and moderately deep cavity necessary for proper alignment of fruit for torque-pitting during processing. Processed flesh color 'a' and hue values were in the desirable yellow to yellow-gold range (Gradziel, 1994; Tourjee et al., 1998), comparable to the Andross cultivar (Table 1). Unlike 'Dixon' and 'Andross', however, 'Kader' showed a decreased tendency to develop undesirable red anthocyanin staining of the fruit pit cavity and associated pit fragmentation. In addition, fruit tend to maintain good processing quality for up to 10 d post-ripening, allowing grower and processor flexibility to provide raw product to the cannery during the critical 'Dixon' gap. Since its release, 'Kader' has become one of the most heavily planted processing clingstone peach cultivars in California, thereby addressing grower and processor needs for a high-quality and good-size peach during the 'Dixon' and 'Andross' maturity seasons.

Availability

Kader is available as a patented (US Plant Patent 26871) cultivar with licenses granted through the University of California Innovation Services, 1850 Research Park Drive, Suite 100, Davis, CA 95618-6134. Propagation material is distributed as registered virus-tested sources through the Foundation Plant Service of the University of California, 1 Shields Avenue, Davis, CA 95616.

Literature Cited

California Canning Peach Association. 2017. Cling Peach Almanac. Sacramento, CA.

Gradziel, T.M. 1994. Changes in susceptibility to brown rot with ripening in three clingstone peach genotypes. J. Amer. Soc. Hort. Sci. 119:101–105.

Gasic, K., J.R. Clark, T. Gradziel, D.H. Byrne, C.H. Crisosto, T. Frett, P. Sandefur, T. Hartman, J.F. Ramirez, N. Bassil, G. Reighard, C. Peace, and A. Iezzoni. 2011. RosBREED facilitates peach genetic improvement via marker-assisted breeding. HortScience 46:S383–S384.

Gradziel, T.M., W. Beres, and K. Pelletreau. 1993. Inbreeding in California canning clingstone peach cultivars. Fruit Var. J. 47:160–168.

Tourjee, K.R., D.M. Barrett, M.V. Romero, and T.M. Gradziel. 1998. Measuring flesh color variability among processing clingstone peach genotypes differing in carotenoid composition. J. Amer. Soc. Hort. Sci. 123:433–437.

Techakanon, C., T. Gradziel, L. Zhang, and D. Barrett. 2016. Effects of Peach Cultivar on Enzymatic Browning Following Cell Damage from High Pressure Processing. J. Agr. Food Chem., doi: 10.1021/acs.jafc.6b01879.

HortScience 54(■):1–3. 2019. https://doi.org/10.21273/HORTSCI14291-19

'Vilmos' Peach: A New and Improved "Stay-ripe" Processing Clingstone Peach Ripening in the 'Andross' Maturity Season

Thomas Gradziel and Sabrina Marchand
Department of Plant Sciences, One Shields Avenue, University of California, Davis, CA 95616

Additional index words. breeding, fruit, stay-ripe

'Vilmos' peach [*Prunus persica* (L.) Batsch] produces a clingstone fruit with nonmelting flesh and is suitable for processing or fresh market. Fruit can maintain quality and firmness for up to 4 weeks after the initial tree-ripe stage. This "stay-ripe" trait allows delayed harvest, including once-over and mechanical harvest when all fruit on the tree have achieved commercial tree-ripe quality. Evaluated as selection UCD-91,9-161, it was derived from a cross between 'Loadel' and breeding selection UCD-F10E,6-27. Ripening time is during the commercially important 'Andross' period, ≈4 d after 'Fay Elberta'. Long-term commercial evaluations have shown that fruit demonstrated very good harvest, postharvest, and processing quality with low susceptibility to fruit brown rot, pit fragmentation, and associated red anthocyanin staining. Fruit possess good size and color that are similar to the commercially important 'Andross' and 'Ross'. Trees have proven to be consistently productive during more than 14 years of commercial evaluation. Tree form is semi-upright, with vigor and branch architecture similar to those of 'Andross'. Flowers are pink and nonshowy. Leaves are medium to dark green with globose glands.

Origin

A main objective of the University of California at Davis (UCD) Processing Peach Breeding Program is the development of replacements for the early maturity season cultivars Dixon and Andross. Recently, the Kader cultivar has been released as a commercially proven candidate for the current harvest gap between the processor extra-early and early harvest seasons. This harvest gap resulted from the removal of cultivars from the list approved by processors of the Dixon cultivar because of problems with splitting and red anthocyanin staining of fruit pits (Gradziel and Marchand, 2019). 'Andross' has become the most heavily planted cultivar for the early maturity season because of its potential to produce abundant firm fruit of good commercial size. Introduced in 1964, 'Andross' originated from a cross with 'Dixon' as a grandparent; therefore, it shares a common germplasm and processing problems. Fruit flesh color is a desirable yellow–gold and possesses good fresh and processed quality, but the fruit pit cavity often develops a red color from the formation of anthocyanins. The anthocyanins oxidize to brown when heat-processed, staining both the processed fruit and syrup. The 'Andross' fruit endocarp or pit is susceptible to breakage, resulting in undesirable pit fragments in the processed product. A harvest gap also exists between 'Andross' as the last commercially important early harvest season cultivar and 'Ross', the first commercially important late season cultivar.

The cultivar Vilmos resulted from a cross between 'Loadel' and F10E,6-27 (Fig. 1) which represents traditional germplasm, with the exception of UCD11,5-61, whose origins remain uncertain (Gradziel et al., 1993). Molecular marker analysis suggests that UCD11,5-61 represents a distinct germplasm lineage, possibly originating in South Africa (Fresnedo-Ramírez et al., 2015). Although too small for commercial production, UCD11,5-61 fruit are unique because they maintain good processing firmness and on-tree quality for up to 10 d after tree-ripe. This trait, which is referred to as stay-ripe because the ripening process is normal but fruit do not deteriorate rapidly after the tree-ripe stage, is highly desirable for processing peaches because it allows greater flexibility and efficiency during harvest. 'Vilmos' is a product of a breeding effort to combine the desirable field production traits of 'Loadel' and 'Carson' with the processing firmness and stay-ripe quality of UCD11,5-61. Originally designated as seedling 91,9-161, it was selected based on its good fruit and tree qualities, its freedom from red staining of the pit, the low frequency of pit fragments in processed fruit, and its desirable ripening time that is the same as or 1 d after that of 'Andross'. Regional evaluation plots for 91,9-161 were established in 2001 at Winters and Davis in the Sacramento Valley area of California, in 2001 at the Kearney Agricultural Center in Parlier in the San Joaquin Valley area of California, and in 2004 at multiple grower evaluation plots in the Sacramento and San Joaquin Valleys under the designation 'UCD-Early#5'. Based on its positive evaluations over 14 years, selection 91,9-161 has been released as the processing peach cultivar Vilmos. The name 'Vilmos' was chosen to acknowledge the extensive contributions to the genetic improvement of peach by Dr. Vilmos Beres during his long career in the Department of Pomology at UCD.

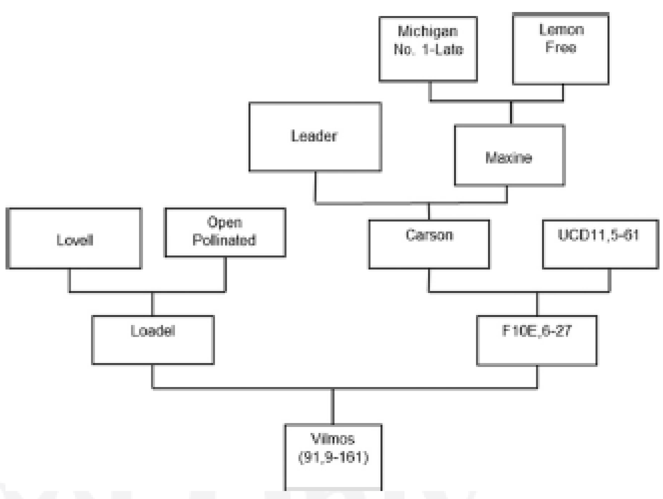

Fig. 1. Pedigree of the 'Vilmos' peach. Seed parent is presented on the left. The origin of the pollen grandparent UCD11,5-61 is unknown.

Received for publication 17 June 2019. Accepted for publication 9 Aug. 2019.
T.G. is the corresponding author. E-mail: tmgradziel@ucdavis.edu.

Description

The 'Vilmos' peach ripens at the same time or just after the commercially important 'Andross'. In addition to the desirable ripening period, the fruit show a low incidence of the undesirable pit splitting and red anthocyanin staining of pit cavities that occur in Andross and other less extensively planted cultivars for this harvest time. The fruit are large and round, with a slight tip, although they are free from the elongated tip found on several clingstone peach cultivars following mild winter and warm spring
2 weather (Fig. 2). The flesh is bright yellow to yellow–gold and shows improved resistance to fruit brown rot caused by *Monilinia fructicola* under both field and controlled
1 laboratory conditions (Table 1). Fruit skin is slightly less pubescent than that of 'Andross', with ≈30% red blush. The pit has a medium size and has remained free from the red staining and extensive pit fragmentation of 'Andross', even in environments promoting these conditions. The tree is upright to semi-upright, with vigor similar to that of 'Andross'. Branch architecture is similar to that of 'Andross', although often with a denser canopy. Flowers are pink, nonshowy, and large, with two flowers commonly present per node. Leaves are medium to dark green, with globose leaf glands, and are similar to 'Andross' in size and shape.

Performance

Trees were evaluated from 2004 to 2018 under standard commercial conditions in the Sacramento and San Joaquin Valleys. Trees produced a medium to high crop comparable
2 to that of 'Andross' (Table 2). 'Vilmos' bloom was uniform and abundant when chilling hours were >650 h using the Utah model (Byrne and Bacon, 1992), as occurred at all Central Valley test sites and years. Bloom time at Central Valley commercial production sites occurred midseason in relation to other commercial cling peach cultivars, similar to 'Kader' and 'Andross'. 'Vilmos' fruit were clingstone and nonmelting. Fully ripe fruit, as determined by a lack of visible green pigmentation on the fruit epidermis, showed an orange–yellow primary ground color with 10% to 40% red blush. Fruit skin had a fine, short, and netted pubescence, with no observed tendency to crack. Some split pits occur in low crop years, although at lower rates than that of 'Andross'. Fruit mass was similar to that of 'Andross' when thinned using recommendations developed for 'Andross' (California Cling Peach Advisory Board, 2017) to achieve commercial fruit diameters of ≥60 mm. Fruit size was similar to that of 'Ross' at the tree-ripe stage, with a firmer flesh more similar to that of 'Andross' (Table 1). Fruit shape (Fig. 2) and quality (Table 1) were similar to those of 'Andross', although with reduced polyphenol oxidase activity and associated flesh browning, similar to those of 'Ross'. Three-year average disease severity ratings for fruit brown rot were significantly lower for 'Vilmos' than for the standards 'Ross' and 'Andross'. Processed flesh color "a" and hue values were in the desirable range of yellow to yellow–gold (Gradziel, 1994; Tourjee et al., 1998), comparable to the 'Andross' cultivar (Table 1). Unlike 'Andross', however, 'Vilmos' showed a much lower tendency for the development of undesirable red anthocyanin staining of the fruit pit cavity and associated pit fragmentation. Fruit production according to regional grower evaluations was similar to 'Andross', but with fewer defects. In addition, fruit tend to maintain good processing firmness and quality for ≥14 d after ripening when compared with 'Andross' and 'Klampt' that also ripen at this time (Table 2). The stay-ripe trait allows growers and processors greater flexibility to provide raw product to the cannery during this critical harvest season. The additional ripening time made possible by this trait also allows more intensive cropping of trees than traditionally practiced. Commercial grower tests showed that 'Vilmos' was intentionally cropped, with an unusually high fruit number by commercial thinning to only 80% of the levels recommended by the California Cling Peach Association (2017), resulting in a yield of 45,732 kg·ha^{-1} of fruit with the mandated commercial size ≥60 mm. This yield is comparable to 39,230 kg·ha^{-1} for standard thinned 'Vilmos' and 38,557 kg·ha^{-1} for standard thinned 'Andross'. The increased yield is a consequence of longer fruit-fill times allowed by the stay-ripe trait and the inherent increased genetic capacity of 'Vilmos' to continue mesocarp growth later in fruit development when adequate resources are available.

Fig. 2. Fruit and leaf morphology of 'Vilmos' peach (grid = 3 mm).

Table 1. Performance of 'Vilmos' clingstone processing peach compared with that of 'Andross' and 'Ross'.

	Andross	Vilmos	Ross
Raw fruit size (g FW)[y]	332.2 b	235.7 a	236.1 a
Raw fruit firmness (kg)[y]	3.4 b	3.3 b	3.7 a
Processed flesh color "a" value[x]	6.9 b	7.2 b	5.3 a
Processed flesh color "b" value[x]	45.9 a	46.1 a	43.3 b
Processed flesh color "L" value[x]	78.1 a	77.7 a	79.7 a
Flesh browning[x]	0.4 b	0.3 a	0.4 b
PPO activity (mL Abs/mi)[w]	383 b	135 a	193 a
Susceptibility to Monilinia fruit rot[v]	9.4 b	6.4 a	16.9 b
Proportion with red pit staining	0.7 b	0 a	0 a

[z]Mean separation performed within each row by Duncan's multiple range test, $P = 0.05$ from a sample size of 50 fruit randomly harvested from 12th leaf trees thinned to achieve a commercial size ≥60 mm.
[y]Fruit firmness was measured with a Magness-Taylor firmness tester using an 8-mm tip with the fruit epidermis removed as described by Gasic et al. (2011).
[x]CIELAB 1976 L*a*b* color space. Flesh browning was measured as the proportion of the 'L' value decrease 12 h after cutting as described by Techakanon et al. (2016).
[w]Polyphenol oxidase (PPO) values are from 10 fruit samples per genotype as described by Techakanon et al. (2016).
[v]Disease susceptibility values are from fruit samples replicated over 3 consecutive years as described by Gradziel (1994). Susceptibility was measured as the product of lesion incidence by average lesion diameter 48 h after controlled inoculation.

Table 2. Average fruit firmness for 'Andross', 'Vilmos', and 'Klampt' processing peaches when harvested at the tree-ripe stage and again at 2 weeks and 4 weeks after the tree-ripe date.

		Avg. fruit firmness, kg (SD)		
			2 wk after	4 wk after
Cultivar	Ripe date	Tree-ripe	Tree-ripe	Tree-ripe
Andross	15 July 2015	2.6 (0 0.7)	1.1 (0.6)	<0.5
Vilmos	16 July 2015	2.9 (0.5)	2.5 (0.8)	2.1 (1.2)
Klampt	18 July 2015	2.9 (0.8)	<0.5	<0.5

Data are from 2015 trees grown under standard commercial conditions.

Availability

'Vilmos' is protected by U.S. Patent USPP29623, and licenses for propagation are available from the University of California Innovation Services, 1850 Research Park Drive, Suite 100, Davis, CA 95618-6134. Propagation material is distributed as registered virus-tested sources through the Foundation Plant Service, University of California, 1 Shields Avenue, Davis, CA 95616.

Literature Cited

Byrne, D. H., and T. A. Bacon. 1992. Chilling estimation: Its importance and estimation. The Texas Horticulturist 18:5, 8–9.

California Canning Peach Association. 2017. Cling Peach Almanac. Sacramento, CA.

Fresnedo-Ramirez, J., M. Bink, E. Van de Weg, T.R. Famula, C.H. Crisosto, T.J. Frett, K. Gasic, C.P. Peace, and T.M. Gradziel. 2015. QTL mapping of pomological traits in peach and related species breeding germplasm. Mol. Breed. 35:166–177.

Gasic, K., J.R. Clark, T. Gradziel, D.H. Byrne, C.H. Crisosto, T. Frett, P. Sandefur, T. Hartman, J.F. Ramirez, N. Bassil, G. Reighard, C. Peace, and A. Iezzoni. 2011. RosBREED facilitates peach genetic improvement via marker-assisted breeding. HortScience 46:S383–S384.

Gradziel, T.M. 1994. Changes in susceptibility to brown rot with ripening in three clingstone peach genotypes. J. Amer. Soc. Hort. Sci. 119:101–105.

Gradziel, T.M. and S. Marchand. 2019. 'Kader' Peach: A processing clingstone peach with improved harvest quality and disease resistance, ripening in the 'Dixon' maturity season. HortScience 54:754–757.

Gradziel, T.M., W. Beres, and K. Pelletreau. 1993. Inbreeding in California canning clingstone peach cultivars. Fruit Var. J. 47:160–168.

Techakanon, C., T. Gradziel, L. Zhang, and D. Barrett. 2016. Effects of peach cultivar on enzymatic browning following cell damage from high pressure processing. J. Agr. Food Chem., doi: 10.1021/acs.jafc.6b01879.

Tourjee, K.R., D.M. Barrett, M.V. Romero, and T.M. Gradziel. 1998. Measuring flesh color variability among processing clingstone peach genotypes differing in carotenoid composition. J. Amer. Soc. Hort. Sci. 123:433–437.