

Evaluating Apricots in Riverside, California: Identifying Productive Cultivars for a Low-Chill Environment

Abstract

Six apricot (*Prunus armeniaca*) cultivars were evaluated for cropping performance in the low-chill environment of Riverside, CA during four crop seasons (2012 through 2015). We evaluated cultivars with high fresh fruit quality in current commercial use that range widely in bloom date. Chill accumulations at the Riverside site ranged from 161 h to 470 h during the study, providing opportunities to evaluate performance under sub-optimal chill conditions. In general, the trialed apricots were not well adapted to the Riverside environment. Irregular bud break and pre-bloom floral bud shed were symptoms common to five of the six trialed cultivars. Cultivar Blenheim was the exception, producing crop loads that required thinning even after a dormant season with only 161 chill hours. Bloom duration (first to full) for 'Blenheim' averaged 35 d in the Riverside plot, leading to a similarly lengthy fruit maturation period. Of the six trialed apricots, only 'Blenheim' could be recommended for non-commercial planting in environments having chill accumulations similar to Riverside, CA.

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Introduction

Apricot (*Prunus armeniaca*) was a thriving tree crop in California during the first half of the 20th century, with nearly 100,000 A under production at its peak in 1926 Foytik [1]. Since that time, production acreage has declined steadily to its current level of approximately 10,000 A. Harvested apricot volume in California has averaged just over 54,000 T annually over the last three reported years Holcomb [2]. Regions of production have shifted as well, with the bulk of the apricot industry now centered in the San Joaquin Valley near Patterson, CA, whereas previous production centers were varied, and extended throughout the milder coastal valleys from south of San Francisco Bay through San Benito county. Riverside County, in inland Southern California, was once a production center for apricot, with nearly 2,300 A under production in 1950 Hesse [3]. While production acreage has declined in California, enthusiasm for the tasty early-season fruit has not diminished, and the percentage of annual tonnage used for fresh sales (38%) is currently at an all-time high (B. Ferreira, President, Apricot Producers of California, personal communication). Poor fruit quality in the supermarket is a common concern for consumers interested in purchasing apricot, and a reason some consumers choose to attempt growing apricot at home. Consumers generally understand that the perishability of ripe apricot demands that it be picked somewhat immature, enhancing shelf-life in the produce bin at the expense of high fruit quality at purchase. Home growers can wait to harvest at their leisure, obtaining the specific fruit maturity of these delicate fruit that they desire.

When apricot production began shifting from the mild coastal valleys to the hot San Joaquin Valley in the 1960s, available cultivars were not adapted to the harsher environment. High-quality cultivars grown in the coastal valleys such as 'Blenheim' developed pit-burn in the high June temperatures when grown

in the San Joaquin, making flesh unattractive for fresh fruit sales Tufts [4]. Initial breeding efforts led to the development of pit-burn resistant cultivars such as 'Castleton' Weinberger [5] and 'Patterson' Anderson [6], and increased apricot acreage throughout the San Joaquin Valley. Four more decades of apricot breeding led to many more new cultivars with improved characteristics and adaptation to the San Joaquin Valley environment. Besides the pit-burn resistance necessary for the high summer temperatures encountered in the Valley, the newer cultivars were also adapted to the higher winter chilling conditions prevalent there. Apricots (as well as other stone fruits) require a period of winter chilling (< 45°F) during dormancy for proper flowering and fruit set.

The chilling requirement varies considerably between cultivars, and growers attempt to match appropriate cultivars with the environment where they will be grown. When apricots are planted in locations where sufficient winter chilling is lacking, poor fruit set and irregular vegetative growth are frequently encountered. Several million consumers live in Southern California cities and there are many who would enjoy producing apricot in an urban environment. However, chill accumulation is lower in Southern California regions as compared with even the most southerly region of the San Joaquin Valley (Table 1). Hence, apricot cultivars that are productive in the San Joaquin Valley may or may not be productive in Southern California, depending on the specific region's annual chill accumulation, and the chill hour requirement of planted cultivars.

The chilling requirement of any given cultivar must be determined empirically

Actual known chill requirements of apricot cultivars are rare. Chill accumulation at any given site can be easily recorded and researchers interested in determining cultivar chill requirements strive to plant cultivar trials over a range of sites with variable

chill accumulation in order to identify that site with a minimum of chill hours and still an adequate crop load. Typically, as data accumulate through increased acreage of cultivars under evaluation over a range of variable chill hour environments, growers learn the minimum chill hour requirements for desired cultivars. This would be the case for 'Blenheim' (Royal) apricot that has been evaluated for decades in numerous Southern California environments and found to be generally productive in locations with less than 400 chill hours Sidnam [7]. Most printed values for cultivar chill requirements are only estimates shown in tree nursery catalogs (<https://baylaurelnursery.com/apricots.html>; <http://www.davewilson.com:8080/product-information/product/apricots>) without any explanation of how specific chill requirements were determined. We are unaware of any published evaluations of apricot cultivar productivity across a range of locations with progressively lower chilling.

Table 1: Average and range of chill unit accumulation (hours < 45°F) in various Southern San Joaquin Valley and Southern California cities, 2010 through 2015.

Chill Hour Accumulation			
City	County	Average	Range
Southern San Joaquin Valley cities			
Arvin - Edison	Kern	859	535 - 983
Kettleman City	Kings	664	443 - 902
Shafter	Kern	1,223	1,096 - 1,432
Southern California Cities			
Camarillo	Ventura	452	136 - 754
Indio	Riverside	361	236 - 452
Irvine	Orange	278	77 - 497
Long Beach	Los Angeles	403	249 - 602
Moreno Valley	Riverside	309	234 - 418y
Oxnard	Ventura	276	160 - 471
Pomona	Los Angeles	437	189 - 629
San Diego	San Diego	100	45 - 207
Santa Barbara	Santa Barbara	263	90 - 422
Santa Clarita	Los Angeles	431	258 - 609
Temecula	Riverside	194	89 - 365

zData from UC Davis Fruit & Nut Research & Information website:
http://fruitsandnuts.ucdavis.edu/Weather_Services/chilling_accumulation_models/Chill_Calculators/?type=chill
yOnly 3 years data available, 2013-2015

Because of the continued interest of consumers and homeowners in apricot cultivation throughout Southern California and the general lack of information on suitability of apricot cultivars for that purpose, an apricot evaluation trial was established in a low-chill environment at Riverside, CA.

Commercially used apricot cultivars with high fresh fruit quality and variable bloom dates / fruit development periods were evaluated to determine their ability to bear fruit in a low-chill environment.

Materials and Methods

Plot establishment and cultural practices

The low-chill cultivar evaluation plot was established on the Agricultural Experiment Station of the University of California, Riverside (UCR) in Riverside, CA. The Burchell Nursery (Oakdale, CA) provided nursery stock for the trial. Six apricot cultivars ('Apache,' 'Blenheim' (aka 'Royal' or 'Royal Blenheim'), 'Helena,' 'Lorna,' 'Patterson' and 'Robada'), all on 'Nemaguard' rootstock, were planted as one year old dormant nursery stock in UCR Field 6A (lat. 33°58'N, long. 117°20'W 996' elev.) during February 2010. Five of the six apricot cultivars (exception 'Blenheim') are successful commercial cultivars grown throughout the San Joaquin Valley. 'Blenheim' is an older cultivar that is still produced commercially to a limited extent, but only in milder coastal valleys.

Specific chilling requirements for these six cultivars are unknown, but estimates for some cultivars have been provided by commercial sources (Table 2). The evaluation plot was planted using a basic rectangular design with rows representing the evaluated cultivars. Five trees of each cultivar were planted with a spacing of 10' between trees in the row, and 12' between rows (363trees/acre). The entire plot amounted to just 0.082 A, and allowed sufficient space for trees of all cultivars to remain uncrowded by neighboring trees during the study period. While the planting design would be considered statistically unreplicated, the linear arrangement of cultivars facilitated the collection of basic data (tree vigor measurements, bloom phenology, ability to set fruit) and provided better photographic opportunities as compared with more robust experimental plot designs. Soil was classified as an Arlington fine sandy loam, well-drained, with the capacity to store 7.1" water in the soil profile. Field 6A was planted previously to citrus in the 1960s, and trees were removed several years prior to planting the apricot trial. Cultivars Apache, Helena, Lorna, Patterson and Robada were also available for study at the San Joaquin Valley Agricultural Sciences Center in Parlier, CA. Established trees of various ages, all grafted on 'Nemaguard' rootstock, were used for comparing bloom periods and fruit maturity seasons with trees grown at the UCR low-chill plot. 'Blenheim' apricot was not available for study at Parlier as the cultivar is not adapted to the high summer temperatures incurred there. Trees received water, as needed, through furrow irrigation. Specific pest control was unnecessary during the growing season during this study, but trees received an annual dormant oil & copper fungicide spray prophylactically to control various insect and fungal pests. Weed control was accomplished through hand cultivation and disking between rows. No nutrients were applied to the low-chill plot from planting through its final harvest period in 2015. The majority of tree pruning occurred in summer each year after the fruit maturity season, generally during July, when trees were less susceptible to *Eutypa* dieback (*Eutypa lata*) Ramos et al. [8]. Summer pruning also opened the dense tree canopies

to allow flower bud development for the following season's crop. Trees of all cultivars were shaped into open vases with four scaffolds.

Table 2: The evaluation plot was planted using a basic rectangular design with rows representing the evaluated cultivars.

Units			
To Convert SI to U.S., Multiply By	U.S.	SI	Multiply By
0.4047	Acre(s)	ha	2.4711
0.3048	ft	m	3.2808
2.54	inch(es)	cm	0.3937
6.4516	In ²	cm ²	0.155
(°F-32)/1.8	°F	°C	(°C*1.8)+32
1.016	Ton(s)	Tonne (s)	0.9842

Data collection

Chill hour accumulations were tracked using the Chill Calculator at the University of California Fruit & Nut Research & Information website

(http://fruitsandnuts.ucdavis.edu/Weather_Services/chilling_accumulation_models/Chill_Calculators/?type=chill) for stations 039 (Parlier, CA) and 044 (UC Riverside). Hours below 45°F were quantified from 1 November through 28/29 February for these locations in each dormancy period during the study. Trunk cross sectional area (TCSA = $\pi \times \text{trunk radius}^2$) was calculated from trunk circumference (Circumference = $2 \times \pi \times \text{trunk radius}$) measurements taken 6" above the graft union. Measurements were made after summer pruning treatments and at the end of the growing season. First and full bloom dates were recorded for each cultivar. First bloom date was recorded when the first visible open flower was observed.

Full bloom date was recorded when approximately 80% of flowers on a tree were open. Typically at this date, some petal fall was also evident. Bloom data were collected at the UCR plot for comparison with similar data collected from trees growing in Parlier, CA. However, 'Blenheim' was not represented in Parlier and only bloom data from UCR were available for this cultivar. Fruit production was assessed in each of four crop seasons (2012-2015), noting each cultivar's ability to set fruit and the relative maturity season. 'Blenheim' was evaluated for fruit quality during the 2012 harvest season. Twenty fruit were harvested from each of the five 'Blenheim' trees and brought to Parlier for analysis. Upon arrival, seven unblemished representative fruit were selected for evaluation from each tree. Skin was removed from a section of the cheek of each fruit for flesh color evaluation.

A chroma meter (CR-400; Konica Minolta Col Ltd., Osaka, Japan) was used to measure hue angle (h°) of the apricot flesh. Fruit firmness was then measured on the skin-removed cheek of each fruit using a handheld penetrometer equipped with an 8-mm tip (D. Ballauf Mfg. Co., Washington DC). Longitudinal sections of

each fruit were cut and combined for juicing to provide estimates of total soluble solids, juice pH and juice acidity. Presented values represent the average and standard deviation of five single-tree replications harvested from the 2012 crop.

Results

Tree vigor at UCR

Climatic conditions at UCR allowed tree growth to continue later in the year as compared with trees grown in Parlier, CA. Actively growing meristems and a lack of senescing leaves were observed on all cultivars in the Riverside plot at the end of December. By contrast, active vegetative growth of apricot became rare in the Parlier environment after early November, and most leaves had fallen from trees of all cultivars before November's end. Tree vigor varied dramatically among cultivars (Figure 1). At the end of the study, trunk cross sectional area of 'Helena' trees averaged 154 cm², more than double the average trunk area of the least vigorous cultivar Robada (71 cm²). Vegetative growth of all cultivars proceeded normally with growth persisting throughout the long growing seasons.

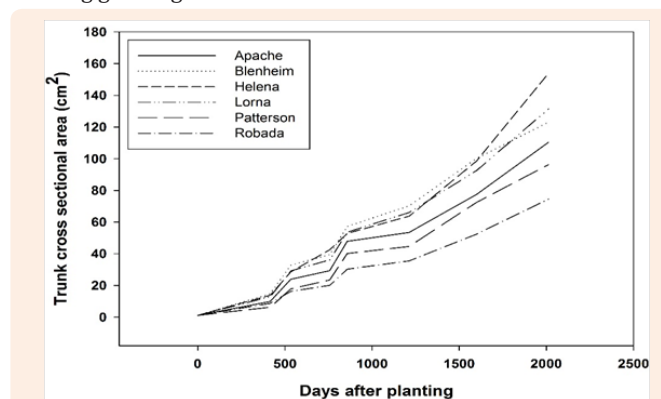


Figure 1: Cumulative trunk cross sectional area (cm²) changes of six apricot cultivars grown in Riverside, CA for five seasons, 2010 – 2015. (cm²* 0.1550 = in²)

Bloom interval

Bloom timings and durations were distinctly different between the Parlier and Riverside locations. For any given cultivar, bloom always began at an earlier date in Parlier as compared with Riverside. Without exception, bloom duration (first bloom to full bloom) was substantially longer in Riverside as compared with Parlier for any given cultivar. During harvest years 2012 through 2015, bloom duration averaged from 11.5 d (Helena) to 16.75 d (Robada) in Parlier, whereas the average bloom duration ranged from 16.25 d (Patterson) to 35.5 d (Blenheim) in the Riverside plot during the same harvest seasons (Table 3). Across cultivars, bloom interval at Parlier averaged 14 d whereas the bloom interval at UCR averaged 23.25 d. Across locations, 'Patterson' had the most rapid bloom interval (14.1 d) and 'Apache' proved to have the lengthiest (20.5 d). Delayed bloom period and extended bloom duration were shown to be common symptoms in peaches of insufficient chilling received during dormancy Weinberger [9].

'Apache' was consistently the earliest blooming cultivar at Parlier and 'Robada' the latest. At UCR, 'Blenheim' consistently began bloom prior to 'Apache,' commencing 19 d and 18 d ahead during the 2014 and 2015 blooms, respectively (Table 3). These conditions were observed after two very low-chill dormancy

periods before the 2014 and 2015 crop seasons where only 173 and 161 chill hours were received, respectively (Figure 2). It was unfortunate that 'Blenheim' was not represented in Parlier to observe its bloom date and duration under higher winter chill conditions.

Table 3: First and full bloom dates with durations (d) of six apricot cultivars grown in Parlier and Riverside, CA for four harvest years.

Harvest Year					
Location	Cultivar	2012	2013	2014	2015
Parlier	Apache	6-24 Feb-19	15 Feb-1 Mar-15	10 Feb-6 Mar-25	13-19 Feb-7
	Helena	16-28 Feb -13	28 Feb-10 Mar -11	24 Feb-4 Mar-9	17 Feb-1 Mar-13
	Lorna	13-28 Feb-16	25 Feb-9 Mar-13	19 Feb-3 Mar-12	17-28 Feb-12
	Patterson	16-28 Feb-13	25 Feb-7 Mar-11	18-28 Feb-11	17 Feb-1 Mar-13
	Robada	23 Feb-16 Mar-22	2-14 Mar-14	25 Feb-10 Mar-14	19 Feb-7 Mar-17
Riverside	Apache	27 Feb-25 Mar-28	2-22 Mar-21	4 Mar-25 Mar-22	7 Mar-2 Apr-27
	Blenheim	23 Feb-20 Mar-27	28 Feb-5 Apr-37	13 Feb-26 Mar-42	17 Feb-24 Mar-36
	Helena	10 Mar-28 Mar-19	6 Mar-29 Mar-24	26 Mar-4 Apr-10	23 Mar-8 Apr-17
	Lorna	8 Mar-26 Mar-19	4 Mar-5 Apr-33	12 Mar-7 Apr-27	15 Mar-5 Apr-22
	Patterson	6 Mar-18 Mar-13	9-22 Mar-14	11-28 Mar-18	14 Mar-2 Apr-20
	Robada	13-30 Mar-18	14 Mar-5 Apr-23	14 Mar-3 Apr-21	17 Mar-5 Apr-20

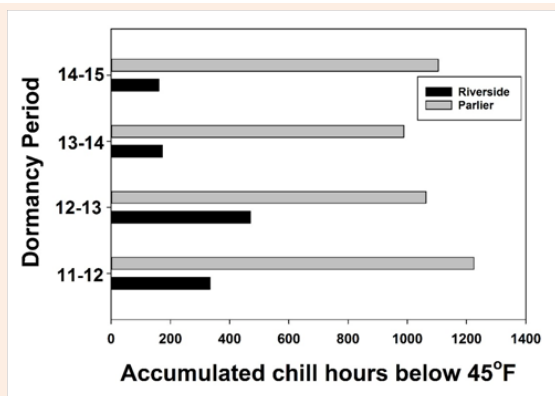


Figure 2: Chill hour accumulation in Parlier, CA and Riverside, CA for dormancy periods prior to crop years 2012 through 2015.

Cropping ability

At the Riverside plot, fruit production was very inconsistent for five of the six trialed cultivars, the same cultivars that produced adequate yields in San Joaquin Valley orchards. Fruit production was very limited in these cultivars, and while they would certainly not be useful for commercial production in Riverside, their utility for backyard production might also be questioned (Table 4). The progression of fruit maturity observed among these cultivars at UCR was the same as what had been consistently observed in Parlier. 'Blenheim' was the exception at Riverside, and all

'Blenheim' trees required extensive fruit thinning in each harvest season for adequate fruit sizing (Figure 3). While somewhat small (40.9 g) for commercial markets, fruit quality of 'Blenheim' produced at UCR was very good, averaging 19.2% total soluble solids from fruit having 12.8N flesh firmness (Table 5). The low acidity observed in 'Blenheim' coupled with the relatively high total soluble solids led to an impressive 43.6 Brix: Acid ratio, indicative of good eating quality. Pit-burning was not observed in mature 'Blenheim' fruit, nor in the small amounts of fruit produced by any of the other five trialed cultivars at that plot. The fruit maturity season for 'Blenheim' was much extended as compared with the other cultivars, presumably due to its unusually lengthy bloom period (Figure 3). Because of the inconsistency of fruit production when grown under the environmental conditions at Riverside, cultivars Apache, Helena, Lorna, Patterson and Robada could not be recommended for planting there or in other low-chill areas of Southern California. Cultivar Blenheim can be recommended for planting, as it produced consistently at the Riverside location, even after receiving as few as 161 chill hours during dormancy.

Discussion

While there were over 2300 A of apricot produced in Riverside County as late as 1950 Hesse [3], apricot production amounted to just 38 T in Riverside County in 2014, accounting for only 17 A of the County's 26,000 A of tree and vine crops Anon [10]. Chill hour accumulation varied dramatically between the Parlier and UCR locations during the course of this study (Figure 2). Chill accumulation received at Parlier during the past 10 dormant

seasons averaged 1132 h. Average chill accumulation during the same period at UCR was only 315 h, less than a third of that received at Parlier. Chill accumulations were well below average prior to the 2014 and 2015 crop seasons at UCR, with only 173 h and 161 h received, respectively.

Table 4: Flowering and cropping abilities of six apricot cultivars cultivated at a low-chill site in Riverside, CA during crop years 2012 through 2015.

Cultivar	Pre Fruit Set Development	Cropping Ability	Recommended for Low Chill Site
Apache	Abundant flower buds	Higher fruit loads in years with higher chilling	No
	Irregular vegetative bud break	Thinning never required	
	Generally weak bloom strength		
Blenheim	Strong extended blooms	Highest fruit loads of the trialed cultivars	Yes
	Distinct 'waves' of bloom with developing fruit & bloom present on tree at same time	Always required extensive thinning	
Helena	Most vigorous cultivar, vegetatively	Higher fruit loads in years with higher chilling	No
	More intense bloom in higher chill years	Thinning was never required 0 – 15 fruit per tree per season	
Lorna	Generally good flower bud development	Poor cropping ability, even at 470 chill hours	No
	Irregular vegetative bud break	0 – 5 fruit per tree per season	
	Pre-bloom bud sluffing		
Patterson	Abundant flower buds	Consistent across years to produce some fruit	No
	Shortest mean bloom duration (16 d) of cultivars at site	Thinning was never required 3 - 30 fruit per tree	
Robada	Weakest of cultivars, vegetative	Poorest cropping of trialed cultivars	No
	Poorest of cultivars in bloom strength	Less than 15 fruit set on five trees in four crop seasons	
	Latest blooming cultivar		



Figure 3: Blenheim apricot trees cultured in Riverside, CA during 2014 produced abundant crops that required thinning, even with as few as 173 chill hours (left). Bloom duration was extended under reduced chill hour conditions, leading to cultivar Blenheim with flower buds, open flowers and developing fruit evident on the same tree (right).

Chill hours received at Parlier ranged from 989 h (2013) to 1225 h (2011) during the study years, well above expected chill requirements for the apricots under cultivation. Five of the six trialed apricot cultivars (exception 'Blenheim') consistently produce adequate yields for commercial production under the environmental conditions present in and around Parlier, CA. High quality 'Blenheim' apricot is still produced on limited acreage in the mild coastal valleys, with 1,400 T (3% of 2016 tonnage) produced statewide in 2016 (B. Ferriera, President, Apricot Producers of California, personal communication). Vegetatively apricot cultivars grew well at the UCR plot, responding to the long growing season that allowed for growth later into the calendar year as compared with growing conditions at Parlier. Adequate summer pruning after the fruit maturity season provided required light for developing flower buds (Figure 4), and all cultivars exhibited well developed flower buds on dormant shoots and spurs while in vegetative dormancy.

Major differences between trees at the two plots became apparent each year as temperatures began to warm and flower buds began to push. Apricot cultivars cultured in Parlier came into bloom with a full complement of floral buds, producing dense

blooms throughout the trees. Vegetative bud break was relatively synchronous throughout the trees of each cultivar, and bloom durations were shorter as compared with the same cultivars planted at UCR. Apricots cultured at UCR by contrast began losing floral buds throughout the trees as temperatures began to warm. Pre-bloom flower bud shedding in apricot has been previously documented as a symptom of insufficient winter chill accumulation Tufts [4]. Bloom density was weak in trees of all cultivars except 'Blenheim,' which seemed unaffected by dormant periods with reduced chill accumulation. Irregular vegetative bud break was a common symptom among trialed cultivars grown at UCR (Figure 5). This phenomenon has been previously documented in peaches when winter chill was insufficient for the planted cultivars Weinberger [9]. Vegetative bud break appeared more uniform in 'Blenheim,' indicating a lower chill requirement as compared with the other five trialed cultivars.



Figure 4: Abundant fruit drop is evident below 'Blenheim' trees cultured in Riverside, CA in 2012. Trees were vigorously pruned after harvest to provide light necessary for proper flower bud development.

Table 5: Fruit physical characteristics and juice chemistry for 'Blenheim' apricot harvested in Riverside, CA during the 2012 harvest season.

Characteristic	Blenheim
Fruit Physical Character	
Fruit mass (g)	40.9 ± 1.0
Axial diameter (mm)	42.1 ± 0.7
Flesh firmness (N)	12.8 ± 0.7
Flesh hue (o)	73.8 ± 0.6
Juice Chemistry	
Total soluble solids (%)	19.2 ± 0.3
pH	3.78 ± 0.08
Acidity (Meq/100 mL)	0.44 ± 0.04
Fruit harvest date	12-Jun



Figure 5: Appearance of 'Lorna' (left) and 'Apache' (right) trees in April 2014 after receiving only 173 chill hours. Both cultivars demonstrate irregular vegetative bud break with large parts of scaffolds devoid of vegetation.

Based on bloom and fruit production data from four crop seasons, five of the six evaluated cultivars could not be recommended for planting in Riverside, CA. Chill accumulation at that location was generally insufficient for those five cultivars. However, higher fruit loads were noted in some cultivars ('Apache,' 'Helena' and 'Patterson') in years where higher chilling was received. Performance of these cultivars might be adequate, at least for non-commercial homeowner production, in locations having a higher average chill accumulation as compared with UCR. These locations would probably be found at higher elevations in Southern California, such as the local mountains; as it is unlikely that any low elevation areas in Southern California would have sufficient chilling for apricot cultivars other than 'Blenheim'. Cultivar Blenheim appears perfectly suitable for non-commercial production in environments with similar chill hours received at UCR. Its extended bloom period might actually be an added bonus for homeowners who would appreciate an extended harvest period, and have fresh ripe apricot available for immediate use.

Acknowledgment

None.

Conflict of Interest

None.

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