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# Dendrochronology reveals planting dates of historic apple trees in the southwestern United States

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**Abstract**

Historic apple orchards grow throughout the United States (5). Reconstructing histories of these orchards can offer valuable insights into local agricultural history and can be important documentation for historically significant landscapes. By applying standard dendrochronology techniques to historic apple orchards in central Arizona and southern Colorado, we successfully cross-dated ring growth between trees in the orchards, compared annual tree growth with local climate conditions, and determined minimum planting dates of the historic orchards. Our results indicate 1903 and late 1940s planting dates for two historic orchards in Arizona. An orchard near Ignacio, Colorado was planted prior to the late 1920s, though heart rot precluded finding the actual planting date. Tree ring dates from apple trees in the historic Pendley Orchard, Slide Rock State Park, Arizona generally compared closely with planting dates described in an oral history of the property, but showed some discrepancies with the older trees, most likely stemming from replanting events in the orchard. Climate response within historic orchards was less evident. One historic orchard showed moderate correlation with precipitation, but orchard growth appears more strongly controlled by local factors including irrigation and orchard maintenance. Our results indicate that if heart rot is absent from historic apple trees, dendrochronology is a useful tool for determining historic orchard planting dates.

Throughout higher elevations of the southwestern United States, remnant historic orchards persist as vestiges of agricultural endeavors in the region. For many of these orchards, the planting dates, cultivars grown, and the histories of the farmers who planted them were never recorded. Historic trees however, provide an extant, living record of homestead agriculture through genetic lineages and environmental influences recorded in annual growth rings. Scientific tools can be used to reconstruct these histories, such as genetic analysis to reveal tree identities (11, 12, 13, 26), tree and orchard architecture as characteristic of different historic periods (5), and dendrochronology to age historic trees (22) and to reconstruct effects of environmental variables such as drought (17). Reconstruction of orchard histories can offer valuable insights into early agriculture not documented in the literature. Knowledge of orchard planting dates can be important in documenting and restoring orchards on historically significant properties. Orchards and fruit trees were integral in U.S. settlement history for food and beverages in subsistence cropping systems and later as commercial plantings of cash crops (5). With the rise of modern orchard practices in the 20$^{th}$ Century, apple cultivar diversity in the U.S. diminished substantially (8, 25). Consequently, in addition to historic value, historic orchards may also contain genetic resources (26). Since many later plantings contain commercial cultivars, understanding orchard ages through dendrochronology may be useful in evaluating conservation priority of historic trees.

The xylem structure of apple [*Malus x sylvestris (L.)* var. *domestica* (Borkh.) Mansf.] is characterized in the Xylem Database (29) as having distinct rings with diffuse porous structure of solitary vessels separated by thin to thick walled fibers. Tree growth in the spring predominates with the formation of more early wood than late wood (17). Orchard growing conditions can present challenges to dendrochronology. Tree-ring widths may reflect only the irrigation schedule of the trees,

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precluding cross-dating (16). False rings in the form of partial double rings have been found (18). Fruit production can reduce ring growth during "bearing" years or result in double-ring formation depending on cultivar (28). Heart rot commonly affects historic apple trees (4) and may ultimately render them unsuitable to dendrochronology. Orchards on primitive farmsteads were often planted with seedling trees, but grafted stock became standard by the mid to late 19th Century (10). Both seedling and grafted trees may be nursery grown prior to planting in the orchard, and it remains unclear how this will affect tree growth or tree-ring dating except that orchard establishment may post date the age of the trees by a year or more depending on how old the trees were when planting in the orchard. Despite these challenges, historic orchards have been aged and cross-dated (22).

Historic literature of apples in the Southwest begins with early introductions of Old World agricultural crops through Jesuit, Dominican, and Franciscan missionary expeditions up the Camino Real from Mexico City to Santa Fe, New Mexico, by 1620 (6, 15). Later introductions came in waves of settlement from eastern and mid-western sources, beginning in California and Utah before 1850 (7, 10). Agricultural settlement closely followed the opening of the region to trappers, miners, and ranchers, and expanded with improvements in transportation routes and irrigation technology. Low annual precipitation confined early orchard growing to flood terraces near streams and springs that could be used for irrigation (7). Pre-20th Century orchards were primarily farmstead and small commercial plantings for home use and to supply local mining and logging boomtowns. The U.S. Department of Agriculture actively participated in plant introductions into the Southwest between 1887 and 1917 through agricultural experiment stations enabled by the Hatch Act of 1887 [Mar. 2, 1887, ch. 314, § 1, 24 Stat. 440,7 U.S.C.361a et seq] (19). Mid-western mail-order nurseries began advertising in the region at least as early as the 1930s. The average lifespan of apple trees is thought to be only 60-100 years (24). Therefore, many of the living historic orchards on the landscape likely date to the later introductions of Anglo settlement of the region.

We analyzed increment cores from apple trees in historic orchards of unknown planting dates to reconstruct planting times, and cross-date their ring growth to determine the extent of environmental variables recorded in the trees. The Historic Pendley Orchards at Slide Rock State Park, Arizona, with oral history planting dates of 1932 in the North Orchard, 1956 in the West Orchard, and 1992 in the Experimental Orchard were ideal for evaluating the application of dendrochronology in assessing historic orchards. Additional cores were taken from abandoned farmstead orchards near Big Bug Creek in the Prescott National Forest, AZ; at Bottle Spring in the Tonto National Forest outside of Young, AZ; and from the Crossfire Ranch outside of Ignacio, CO to determine planting dates (Fig. 1).

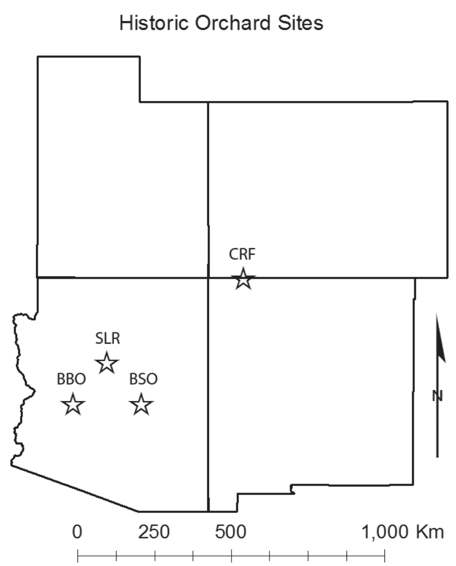


**Fig. 1.** Sample collection sites: Pendley Orchard at Slide Rock State Park, AZ (SLR), Big Bug Orchard in the Bradshaw Mountains, AZ (BBO), Bottle Springs Orchard near Young, AZ (BSO), and Crossfire Ranch Orchard, near Ignacio, CO (CRF).

## Materials and Methods

*Collection sites.* Trees from the historic Pendley Orchard at Slide Rock State Park were cored in February 2010. Four trees were cored from the 1932 North Orchard, from trees 207 ('Delicious'), 211 ('Wolf River'), 228 ('Delicious'), and 248 ('Delicious') as maintained in the Slide Rock Orchard database and labeled with aluminum tags at the base of each tree. Five 'Delicious' trees were cored from the 1952 West Orchard, from trees 264, 288, 292, 295, and 297. Three trees were cored from the 1992 Experimental Orchard, from trees 323 ('Braeburn'), 326 ('Fuji') and 359 ('Lura Red'). Tree cultivars, planting dates, and numbers are documented in Tom Pendley's Oral History (23) and in the Slide Rock State Park Orchard restoration final report (21).

Twelve trees from the Big Bug Orchard were cored in May 2010. Trees were labeled with small aluminum tags by the author in 2007 during genetic sampling of the orchard (26). Genetic analysis revealed 'Westfield Seek-no-Further' as the dominant cultivar in the orchard, precluding it from being a seedling orchard.

The Bottle Springs Orchard was cored in March 2010. These trees appear to be largely seedling plantings based upon their multi-trunk nature and observations of fruits made by the authors in fall 2007. Trees were assigned numerical identifiers and GPS locations were recorded, but no tags were nailed to trees. Three apple trees and five Ponderosa pine (*Pinus ponderosa* C. Lawson) trees growing within the orchard were cored. Four trees from the Crossfire Orchard were cored in May 2010. All trees were affected with heart rot in this orchard and no complete cores were extracted.

A single core was extracted from each tree using a 3-thread, 5.15 mm increment borer (Haglöf, Sweden), except in instances where heart rot or internal branching or injury prevented extraction of a usable core. In these instances, two cores per tree were extracted. Two cores were extracted from each of five Ponderosa pine trees in the Bottle Springs Orchard. Cores were mechanically sanded using 220-400 grit sandpapers. To determine the age of trees and assign a calendar date to individual growth rings, we used a technique called cross-dating. Tree growth is influenced by factors at the individual tree scale (such as pruning or differential watering), and also at the site to regional scale by factors such as climate. Cross-dating matches the common growth patterns among trees at each site and helps identify missing rings and other issues such as false or double rings discussed below. We used graphical

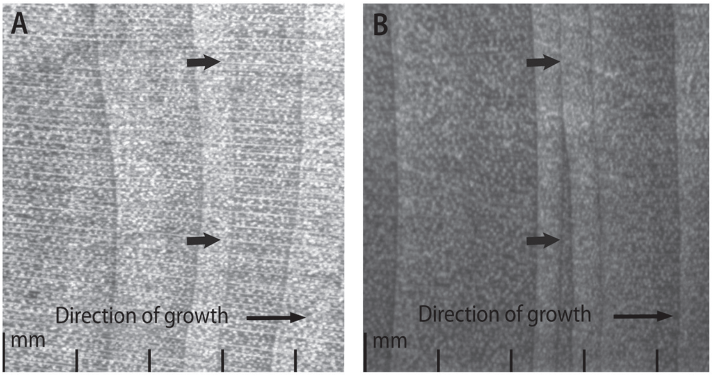


**Fig. 2.** Cross sections of apple wood revealing defuse-porous cell structure and annual ring growth. Cross section A (above left) depicts an incomplete double ring; cross section B (above right) shows a partial ring pinching out.

(27) and statistical (9, 14) methods to cross-date the samples from each site. We then measured the ring widths to generate raw ring-width series from each tree. A 50-year cubic smoothing spline (2) was applied to the raw measurement series to standardize and remove biological growth trends. The standardized series were then compiled into individual orchard chronologies (1). Tree growth within orchards was compared to climate records of precipitation and maximum summer temperatures using correlation and partial correlation analysis (20) with gridded PRISM data (3).

## Results and Discussion.

*Cross-dating*. Ring widths were cross-dated among trees within all historic orchards surveyed. Cross-dating, however was much more difficult for young trees and trees in orchards still being maintained than in the older rings of abandoned orchards. Double or false ring formation (two apparent growth rings during the same year, Fig. 2A) can make cross-dating difficult and appears to be mostly associated with young, fast-growing wood. Missing rings and partial rings can also complicate cross-dating but were encountered in only one of the Slide Rock cores. Missing and partial rings occur when a tree is under stressful conditions and cannot generate a growth ring everywhere in the tree (Fig. 2B). Raw ring width chronologies for all trees cored in the four orchard sites are plotted in Fig. 3. This figure reveals growth variance among trees within each orchard.

*Slide Rock planting dates*. Tree ages were determined for Slide Rock State Park (Table I) and compared to orchard establishment dates in the Tom Pendley Oral History Project (23) and Park Service records for the 1992 Experimental Orchard. Several factors can contribute to individual trees ages not matching the exact date of orchard establishment. Nursery-grown fruit trees are typically sold at two years of age, but can be three or four years old if too small or not sold in the first seasons. Trees can be added as later

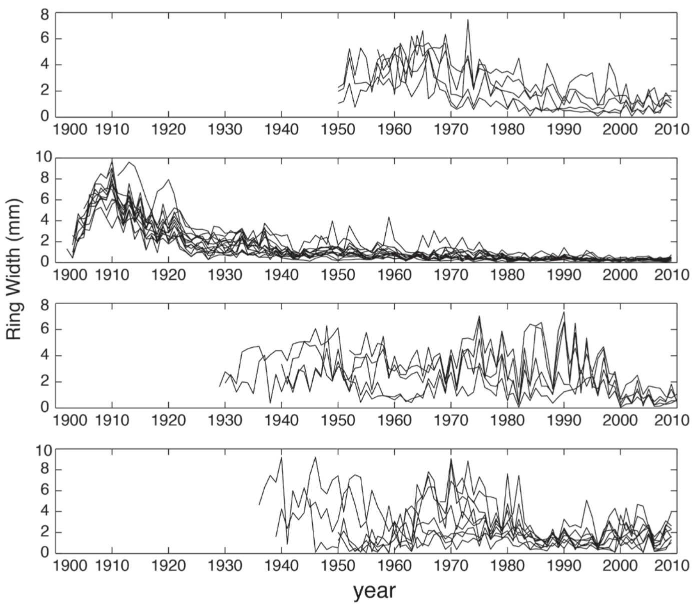


**Fig. 3.** Raw ring-width series plotted for each tree cored in the Bottle Springs, Big Bug, Crossfire, and Slide Rock orchards.

**Table 1.** Planting dates and inner dates of apple trees in the Pendley Orchards at Slide Rock State Park.

| Orchard | Tree | Variety | Orchard Date | Inner Date | Pith |
|---|---|---|---|---|---|
| North | 207 | Delicious | ~1932 | 1936 | No pith |
| North | 211 | Wolf River | ~1932 | 1948 | No pith |
| North | 228 | Delicious | ~1932 | 1970 | Near pith (1-2yrs) |
| North | 248 | Delicious | ~1932 | 1938 | Near pith (2+ yrs) |
| West | 264 | Delicious | ~1956 | 1954 | Near pith (4+ yrs) |
| West | 288 | Delicious | ~1956 | 1956 | No pith |
| West | 292 | Delicious | ~1956 | 1955 | Near pith (~3+ yrs) |
| West | 295 | Delicious | ~1956 | 1967 | Near pith (~3+ yrs) |
| West | 297 | Delicious | ~1956 | 1944 | Pith? (0-1yr) |
| Experimental | 323 | Braeburn | 1992 | 1988 | Near pith (1-3yrs) |
| Experimental | 326 | Fuji | 1992 | 1991 | Near pith (~3yrs) |
| Experimental | 359 | Lura Red | 1992 | 1993 | Near pith (~2yrs) |

replacements, or an orchard may be planted over a period of several years. In addition, if historic trees contained heart rot or the core did not hit pith, the exact age of the tree is also not precisely known. Inner-dates of the 1992 Experimental Orchard correspond well to this planting date. Inner dates from older orchards indicate 1930s and 1950s establishment dates, but are not precisely aged to single planting events. Specifically, tree number 228 in the North Orchard had an inner date of 1970 while the orchard establishment from oral history was nearly 40 years earlier. A later planting to fill in open spaces could explain this anomaly. In addition, tree number 297 in the West Orchard showed an inner date of 1944, predating the establishment of this orchard by more than a decade. It is possible an orchard existed at this site prior to the 1956 plantings that correspond to the oral history and ages of other trees in the orchard.

*Unknown orchards*. Individual orchard chronologies were developed for the orchards included in this study (Fig. 4). The year 1903 is the likely planting date for the Big Bug Orchard. Tree piths all date to 1901 or 1902, but 1903 had a very narrow growth ring. Being named cultivars, the trees were grafted. Typically, nursery apple trees would be grafted at one year of age, 50 – 80 mm off the ground, then grown a year before being sold. The very small ring in 1903 could have been when the trees were first transplanted and establishing new roots in the first season. Below average precipitation for 1903 could have also contributed to this narrow growth ring. The Bottle Springs Orchard dates to 1946, and the Crossfire Orchard dates to at least the 1920s, though heart rot in the trees prevented actual orchard establishment dates from being determined.

*Climate*. Where there was a relationship between the apple tree-ring chronologies and climate, growth responded strongest to annual precipitation ending in July of the current growth year (Fig. 4). This is due to spring-dominated growth responding to soil moisture accumulated over previous months. Tree-growth in apple orchards still being maintained at Slide Rock show no significant correlation to climate, nor was there significant correlation in the now abandoned Big Bug Orchard, possibly due to shallow groundwater associated with Big Bug Creek nor with the Crossfire Orchard that receives ditch irrigation during the summer months. Tree-growth in the Bottle Springs Orchard, in contrast, shows a moderate correlation to precipitation

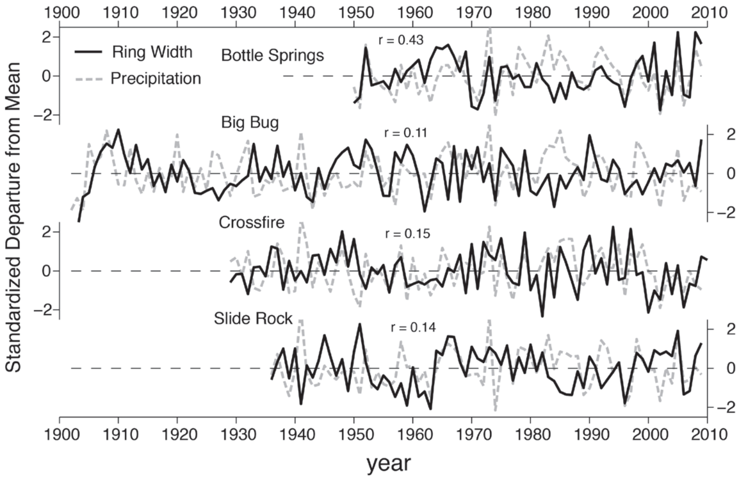


**Fig. 4.** Tree-ring chronologies developed for the four apple orchards. Local 12 month precipitation (3) ending in July for each site is plotted with a dashed gray line behind the orchard chronology. The tree-ring and precipitation series were normalized to z-scores (normalized departures from the mean), so that all the series have a mean of zero and standard deviation of 1. This was done so tree-growth and precipitation are in the same units and are comparable to each other.

(r = 0.43). Dry years were recorded by narrow annual rings but average precipitation years are more variable in ring growth. Ponderosa pines growing within the Bottle Springs Orchard pre-date the planting of the orchard by over 10 years (the oldest Ponderosa pine had an inner date of 1931), which is interesting from a land-use perspective, where the apple trees were planted between young pines. Ring growth of the pines show a lower correlation to precipitation than the apple trees (r = 0.30), indicating different levels of sensitivity at this site between the species.

## Conclusions

This study confirms the utility of dendrochronology in aging historic apple trees and determining historic orchard establishment dates, but also reveals challenges with ascribing exact ages to orchards or individual trees. Cross-dating between trees within the orchards indicates the response of apple trees to external environmental variables such as climate or orchard management regimes and can be useful in reconstructing environmental histories associated with the historic orchards, though the ability to differentiate between these external variables remains unclear. Heart rot appears common in older apple trees and precluded exact dating of the Crossfire Orchard. Results from this study indicate that under favorable conditions, dendrochronolgy methods can determine orchard establishment dates, though heart rot may render these results inconclusive.

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