Almond *Prunus amygdalus* L.

Pollination discovery started it all

Almonds are one of the most successful crops grown in California today. With annual production over 1.25 billion pounds and a value well over $2 billion, almonds are the nation's largest specialty-crop export and California's top agricultural export. The birthplace of the modern California (and western U.S.) almond industry could be considered Suisun, located between UC Berkeley and Davis. It was there, in the late 1870s, that nurseryman A.T. Hatch selected the variety **Nonpareil**, which, because of its good kernel quality and high productivity, would become the industry standard.

Frequent crop failures were common until the 1920s when the classic work of W.P. Tufts and G.V. Philp at the Agricultural Experiment Station showed almond to be self-incompatible, requiring both pollinator varieties and honey bee pollinators to transfer compatible pollen between otherwise self-sterile varieties. From that time on, most breeding efforts have focused on developing pollinator varieties with good commercial quality to provide pollen for the late, mid-, and in particular, early bloom of the dominant Nonpareil variety.

From 1923 to 1948, almond breeding at UC Davis was a joint venture between Milo Wood of the USDA and Arthur Davey of the Agricultural Experiment Station. Their work resulted in the release of the widely planted, early-flowering pollinators **Jordanollo**, **Harpereil**, and **Davey**, which eventually failed due primarily to their susceptibility to disease and pests, thus demonstrating the need for improved resistance.

Dale Kester took over the UC almond breeding program in 1948. He targeted the development of more locally adapted pollinator varieties including **Solano** and **Padre**, which continue to have wide plantings. Kester also released the specialty-market varieties **Kaperiel** and **Milow**, developed to supply high-quality, small-kernel almonds required by the candy industry for chocolate bars, etc.

The industry faced a serious challenge at that time with the deterioration of the major varieties, particularly Nonpareil, from virus contamination and a poorly understood genetic aging disorder, now known as noninfectious bud-failure (BF). In response, Kester's program helped pioneer the development of clean-stock programs for supplying the nursery industry with virus-free plant propagation material as foundation stock.

Kester then applied this experience in vegetative clone deterioration to the bud-failure problem, perceiving it to be associated with the aging/deterioration of a critical gene function rather that resulting from virus/viroid contamination. His ingenious and now classic solution was to exploit the time-capsule effect of very early developed dormant buds at the base of Nonpareil trees (which could be over one hundred years old), which he showed to be suspended in genetic age to approximately that of the original seedling Nonpareil tree. This work led directly to the rehabilitation and continued commercial viability of the Nonpareil and **Carmel**, which currently make up over 50 percent of the total acreage of almonds in California.

Kester also developed a series of interspecific crosses between almond and related species, including peach, as potential rootstocks and sources of new germplasm. The **Hansen** and **Nickels** hybrid rootstocks, which exploited the hybrid vigor of the interspecies (almond × peach) cross, were bred to promote rapid tree growth in orchard replant situations and almond production on marginal soils.

In the early 1990s, Thomas Gradziel took over the almond breeding program. Using and expanding the interspecies gene pool developed by Kester, the current program continues to focus on developing pollinator varieties with improved resistance to diseases and insect pests with support from the Almond Board of California and the Agricultural Experiment Station. Climate change and the related insect pollinator collapse, however, have imposed the concurrent need to rapidly transform almond from a self-sterile to a self-fruitful crop. The development and early utilization of molecular markers, in collaboration with Abhaya Dandekar, has allowed accelerated breeding progress. The inter-species breeding platform offers rich opportunities for both basic and applied genetic research in the areas of gene mapping, gene discovery, and trait dissection.

Gradziel's team has released two partially self-compatible varieties — **Winters** and **Sweetheart**. Winters provides excellent bloom overlap with the early to mid-Nonpareil bloom. This also provided exceptional yields without the need for its own early-bloom pollinator. Sweetheart combines the self-compatibility and high kernel oil quality genes from peach with local adaptation and insect resistance from almond. The next generation of advanced almond selections that combine self-fruitfulness with a wider array of resistance, and quality and productivity genes from multiple species sources, are currently undergoing regional grower testing.

The continuing integration of advanced field- and lab-based technologies towards the goal of applied cultivar breeding has made the UC Davis program an international center for almond genetic research.

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