Almond Bud-Failure

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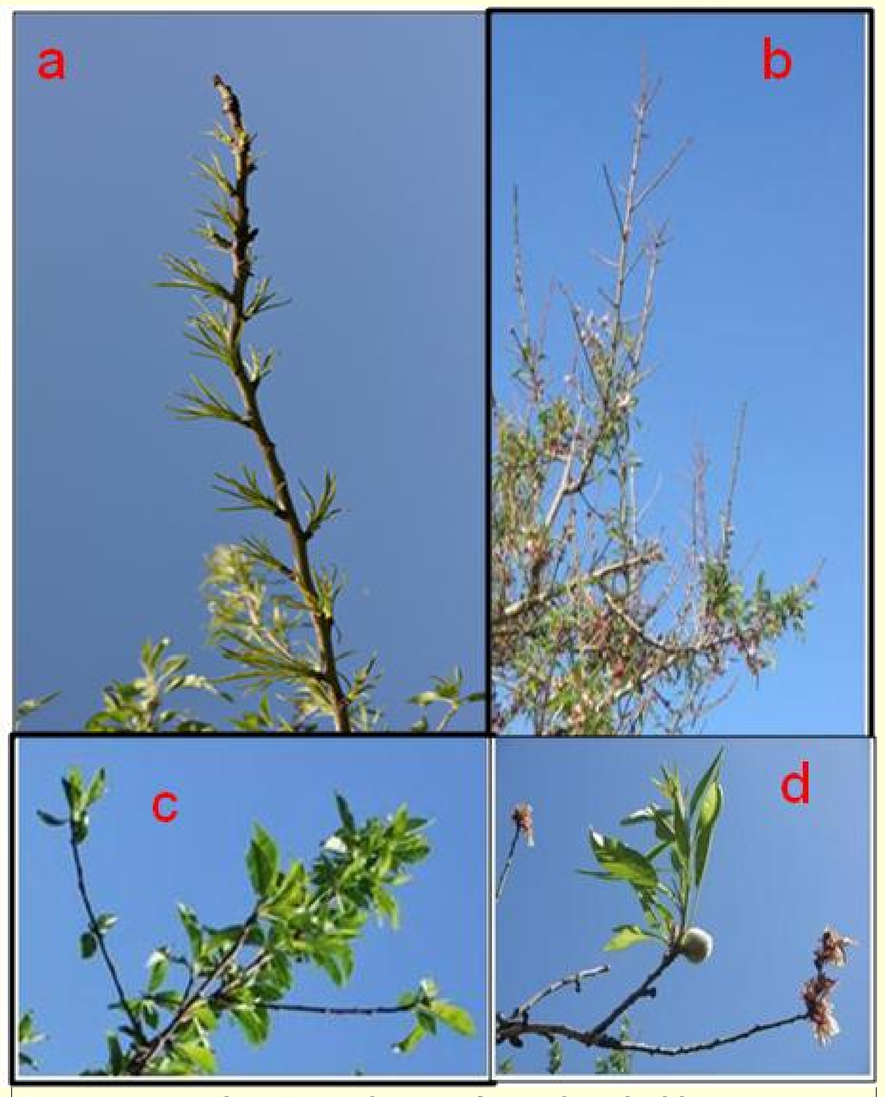
Location: Dept. of Plant Sciences, Univ. of California/Davis

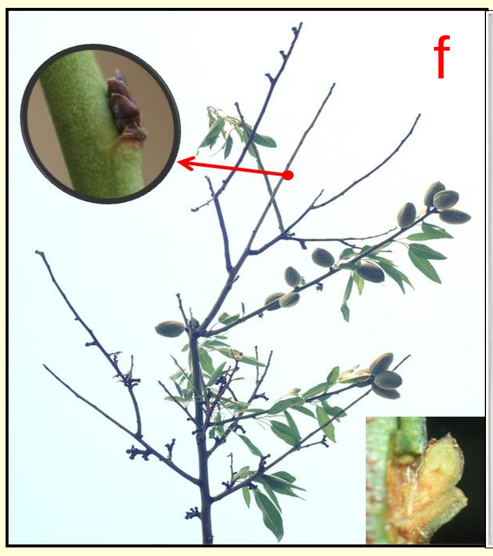


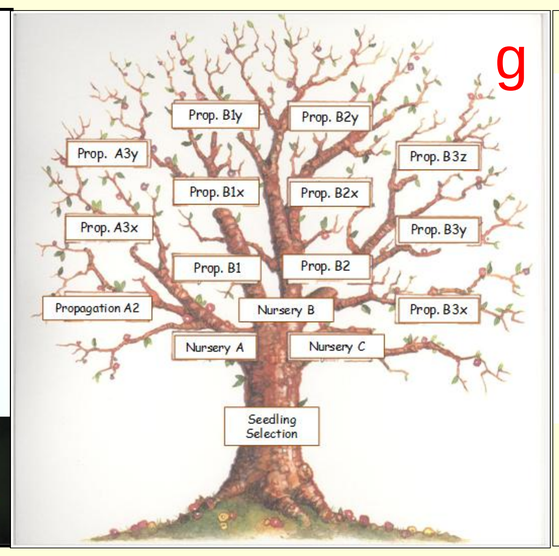
Common growth patterns frequently confused with noninfectious bud failure (a- nutrient deficiency, b- genetic late-leafing-out, c- low winter chill, and, d- virus infection).

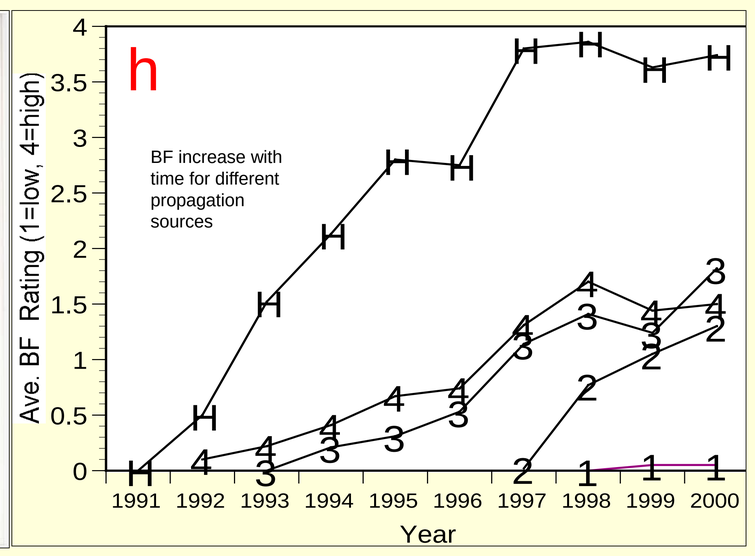
Introduction.
Non-infectious Bud-Failure (BF) remains a major threat to almond production in California. It is a particularly serious problem for the commercially important cultivars Nonpareil and Carmel, which together make up approximately 50% of total plantings. Clonal selection of low BF sources has allowed continued plantings of both Nonpareil and Carmel after BF first became a problem in these cultivars. However, BF-potential (which is related to the age and propagation history of the cultivar) in even the best clonal sources of Carmel may not be sufficiently low to ensure continued commercial use. Careful selection of low-BF Nonpareil clones in the 1970s, 80s and 90s has allowed continued plantings of this dominant variety, though recent BF expression in some Nonpareil sources caution that they may also be progressing towards a new round of BF expression. High BF expression was also a major contributor to the early abandonment of otherwise very promising cultivars such as Merced, and will likely be found in some of the recently released California varieties, particularly those which have the BF-susceptible cultivar Nonpareil as a parent (which includes virtually all currently commercially important cultivars).

True noninfectious bud failure is 'noninfectious' i.e. it cannot be transmitted to other trees by budding or grafting and is not the consequence of nutrient deficiencies or chemical toxicities. In contrast, bud-failure from nutrient deficiencies/toxicities (including some herbicide toxicities) often show some bud development during the winter chilling period and subsequent spring growth, as is the case with zinc-deficiency in **(a)**. Leaf and shoot appearance is often characteristic of the specific toxicity/deficiency. Normal growth can also be restored with the proper nutrient treatment. Similarly, some varieties such as the late-blooming variety Savanna (**b**) show a late leafing-out on terminal shoots that give an early impression of BF. Close examination of shoots, however, typically show buds are developing although at a delayed rate. This can also be confirmed by revisiting the orchard 1to 2 weeks later when normal shoot development should be observed. In years with low winter-chill, some varieties, including Carmel, may also show a delay in terminal or sub-terminal lateral bud development **(c).** Again, a close examination of the buds will show some degree of swelling or development from the previous fall, ruling out noninfectious bud failure. As with late blooming varieties, buds may continue development at a later date, though in some cases they appeared to become dormant or even desiccated. A similar appearance is sometimes caused when shoots or branches rub together in the wind causing the sloughing of buds. Finally, a form of bud failure often observed on old trees is caused by virus infection (typically Prunus Necrotic Ringspot Virus). Where noninfectious bud failure will typically first appear in the more rapidly growing shoots at the tops of trees, virus or infectious bud failure tends to be more prevalent at the slower growing shoots on the lower branches. New shoot growth tends to show shortened internodes and be willowy, giving a 'mules-tail' appearance as seen for PNRV infection common in commercial propagation sources for the variety Marcona (**d**). Diagnosis of virus or infectious bud failure is by graft or bud transmission to a susceptible host, or by molecular analysis (see **i**).

'Rough-bark' trait sometimes observed in severe noninfectious bud failure.







i. ELISA Testing for Marcona

	PNRSV	PDV	Established Source-clone
Marcona, tree BL7	positive	negative	
Marcona, tree DRT3	positive	negative	
Marcona, tree DRT4	positive	negative	
Marcona, tree DRT7	positive	negative	
Marcona, tree DRT11	negative	negative	UCD/FPS-03-71-01-09
Marcona, tree DRT14	positive	negative	
Marcona, tree DRT18	positive	negative	

Expression. True noninfectious-bud-failure (BF) is characterized by the death of terminal or sub-terminal shoot buds during the previous fall, which can be verified by a brown necrosis of the internal bud tissue at that time -see insets in(**f**) as well as an arrest of all bud swelling and development during the subsequent winter and spring. The disorder becomes evident with the failure of buds to grow the following spring resulting in sections of blind or bare shoot-wood with the subsequent pushing of the still-viable basal vegetative buds. Flower buds are not affected and can often develop into fully formed nuts despite the absence of nearby leaves. A third distinct BF characteristic is that once bud-failure symptoms develop, normal growth is not restored in subsequent seasons but rather the disorder gets worse with each following season (though the extent and rate of failure may vary depending upon growth rate, heat stress, etc. from the previous summer). This recurring sequence of terminal shoot failure followed by pushing of viable basal buds, results in a punctuated and erratic shoot development pattern commonly termed "crazy top" (**f**). In severe cases of BF, the bark on young shoots develops a characteristic cracking called 'rough bark' (**e**). BF results from a genetic aging process and so will first be expressed at the oldest, terminal portions of the tree. This tree model (**g**) for BF increase is also analogous to the variety's commercial propagation. The trunk would represent the original breeder developed tree and each branch would represent different nursery propagation sources (clonal sources). As the clonal source (branch) becomes more distant from the trunk through multiple propagation cycles, the BF potential for expression increases. The BF-potential of different clonal-sources can be determined by growing trees propagated from these different sources-clones over many years under conducive climates and observing the rate of BF development (**h**) though this is laborious and time-consuming. Because some virus infection similarly degrades source-clone quality, propagation sources also need to be virus tested and virus-free source clones identified (as was recently achieved with the variety Marcona (**i**) where virus free propagation material (foundation clone source) is currently being established as nursery foundation stock UCD/FPS-03-71-01-09.

j

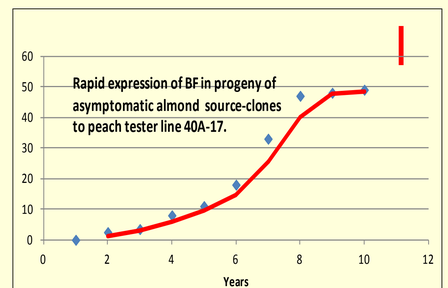
Variety	DELTA	KERN	FPMS	Grower
Aldrich	-	-	-	-
Butte	-	-	-	-
Chip's	?			
Donna	-	-		
Fritz	-	-	-	-
Jenette	-	X		
Jiml	-	-		
Johlyn	-	?		
Kahl	-	?		
Kaperiel	-	?	-	
Livingston	-	-		
Milow	-	-	-	
Mission	-	-	-	X(rare)
Monterey	-	-	-	
Morley	?	-		
NPU	-	-	-	-
Padre	-	-	-	
Peerless	-	-	-	
Plateau	-	-		
Price	-	-	-	
Rosetta	-	-	-	
Ruby	-	-	-	
Sano	?	-		
Savana	?	-		
Sonora	-	-	-	-
Wood Colony	-	-		
Yokut	?	X		
Winters	-	-	-	X
2-19E	-	-	-	-

k

Proportion of different sources showing BF			
2012 Data	DELTA	KERN	FPMS
CARMEL#1			
3-56-1-90	7%	26%	-0
NONPAREIL			
3-8-2-70		9%	-0
3-8-6-72		7%	-0
3-8-5-72	-0		
3-8-8-72	-0		-0
3-8-16-90			-0
3-8-12-72			-0

Control. Because BF is nonreversible, control is primarily through the identification and utilization of low-BF clonal sources for each susceptible variety, combined with careful field monitoring of BF-stability. Results from 2011-12 BF surveys at the Delta and Kern Regional Variety Trials as well as grower trials and FPS foundation sources are summarized in **(j)** and (**k**). Currently, the determination of BF-potential in asymptomatic clonal sources can only be determined through long-term vegetative progeny tests (h) and shorter-term (4-6 years) test-crosses to established peach testers (**l**). Current evidence (see below) indicates that there is no genetic difference in high-BF and low-BF selections of the same almond clone, but rather the state (i.e. turned on or off, etc.) of the controlling gene is affected. Almond is a diploid and so each clone can have two distinct BF-controlling factors (alleles), where the presence of a BF-expression factor could be masked by the presence of a normal factor. Because peach does not appear to have a BF-type gene, progeny from peach crosses will have an equal chance of inheriting either almond parent BF factor. If both factors have high BF potential then all progeny will quickly show BF. If only 1 of the 2 factors has high BF, approx. half of the progeny will inherit that factor and will quickly segregate for BF expression, as has now been documented with several hundred progeny from such crosses (**l**). Based on the tree model of BF (**g**), clonal sources closest to the original tree origin would have the lowest BF potential, as has been verified in vegetative progeny tests. [Clone #1 in (**h**) is the original seedling Carmel tree]. Similarly, rehabilitation of high-BF almond varieties to a lowered BF status can sometimes be achieved by 'pushing' basal epicormic buds from older trees of that variety as the genetic aging appears suppressed in these basal epicormic meristems [fig.(**m**)] . [Origin for several Nonpareil clonal sources in (**k**)].

l



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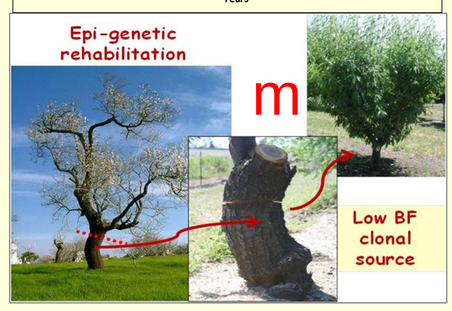

Developing Molecular diagnostics.

Molecular markers represent powerful tools for diagnosing genetic differences. Because clones are genetically identical, the difference between high-BF and low-BF clones of the same variety appear to be the result of different states of activity for the controlling gene rather than distinct genetic differences. (See below for examples). Because the controlling BF-gene appears to segregate as a single gene in crosses to appropriate peach testers (see **l**), molecular marker analysis of appropriate almond by peach-tester populations should be capable of identifying the general location of the BF-gene which could then be more precisely characterized through gene sequencing, etc.. A major potential advantage of molecular diagnostics is the rapid detection of significantly high BF-potential in otherwise asymptomatic clones. Towards this goal, clonal sources and associated crosses with peach BF-testers are currently being developed. [Currently 22 separate clonal sources and 314 peach-almond hybrid progeny are being developed/ maintained].

Molecular marker analysis. Testing for genetic differences between high and low BF clonal sources. Over 500 molecular markers covering all of the 8 almond chromosomes were compared between a normal and high-BF-Mission clone. Markers were typically 5-10 mu apart so that they should be able to detect most genetic recombinations. No genetic differences were detected (though very small (point) mutations might still be undetectable). [Each marker is indicated by a colored band; different chromosomes have differing physical and genetic sizes.]