Field Evaluation of Almond Rootstocks

Project No.: **07-HORT4-Duncan**

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Introduction:

Several new rootstocks, including many from other countries, have recently become available to plant in California. Some of these are reported to have attributes that Nemaguard and Lovell do not posses, such as good performance in replant situations or tolerance to oak root fungus (*Armillaria mellea)*. These rootstocks need to be tested for compatibility with common California almond varieties and to be challenged under California growing conditions.

Objectives:

1. Evaluate the field performance of Nonpareil and Carmel almonds on sixteen rootstocks in an unfumigated, sandy loam, replant location.
2. Evaluate alternative rootstocks for tolerance to Armillaria root and crown rot (oak root fungus).
3. Evaluate the compatibility and field performance of new, alternative rootstocks on several almond varieties.
4. Evaluate the compatibility and field performance of newer almond varieties on Marianna 2624.

A. Field Performance of Sixteen Rootstocks in an Unfumigated, Sandy Loam, Replant Location.

Project Leader: Roger Duncan, UCCE Farm Advisor; Stanislaus County

Project Cooperators: Peter & Christene Bacon, Eric Gemperle - Growers

Interpretive Summary:

Many locations in the "traditional" almond growing areas of the Northern San Joaquin Valley are now being planted with second and third generation almond orchards. In the sandy loam soils common to these areas, new orchards often struggle with the replant problem unless they are fumigated first. The replant problem involves parasitic nematode species and an ill-defined microbial component. Even after fumigation, the most commonly planted rootstock (Nemaguard) is often colonized by ring nematodes and succumbs to bacterial canker. In this trial, sixteen rootstocks were planted to document their compatibility with Nonpareil and Carmel and to examine their horticultural characteristics and performance in an unfumigated, sandy loam, replant location.
In January, 2003, a replicated field trial with Nonpareil and Carmel almond varieties on sixteen rootstocks was planted in a commercial almond orchard. An old almond orchard on Nemaguard rootstock was removed one year prior to replanting. Tree sites were backhoed with an excavator in the fall prior to planting but were not fumigated. The soil type is a Hanford sandy loam. The orchard spacing is 17' x 21' (122 trees per acre) and is flood irrigated. Rootstocks and their parentage are listed in Table 1 below.

Table 1. List of Rootstocks Planted in Almond Replant Trial. Ceres, CA

Rootstock	Parentage	Origin
Nemaguard	Peach (*P. persica x P. davidiana*)	USA
Lovell	Peach 1882 processing peach selection	USA
Guardian SC-17	Peach (OP seedling of S-37 x Nemaguard	Clemson University
Avimag (a.k.a. Cadaman)	Peach (*P. persica x P. davidiana*)	France & Hungary
Empyrean #1 (a.k.a. Barrier 1)	Peach (*P. persica x P. davidiana*)	Venice, Italy
Hansen 536	Peach x almond	UC Davis
Nickels	Peach x almond	UC Davis
Cornerstone (a.k.a. SLAP)	Peach x almond	Burchell Nursery
Paramount (a.k.a. GF 677)	Peach x almond (open pollinated)	France
Empyrean #2 (a.k.a. Penta)	*P. domestica* open pollinated	Rome, Italy
Empyrean #101 (a.k.a. Adesoto)	*P. insititia*	Zaragoza, Spain
Julior	*P. insititia* x *P. domestica*	France
Krymsk 86 (a.k.a. Kuban 86)	*P. cerasifera* x *P. persica*	Russia
P30-135 (a.k.a. Controller 9)	*P. salicina x P. persica*	USDA
Atlas	Complex hybrids possibly containing Nemaguard, Jordanolo almond and flowering plum (*P. blireiana*)	Zaiger Genetics
Viking		Zaiger Genetics

Nematodes: Soil was sampled in February of 2007 and 2008 to determine rootstock suitability for hosting pathogenic nematodes. Although the site was not fumigated prior to replanting, pathogenic nematode numbers remain at low – moderate levels except in the most susceptible rootstocks. Hansen, Nickels and Cornerstone (all P/A hybrids) as well as Julior and Adesoto are highly susceptible to ring nematode and therefore represent a high risk of developing bacterial canker in canker prone soils (Table 2). Viking, Barrier 1, Guardian, Paramount and Kuban 86 continue to host extremely low numbers of ring nematodes. Viking and Guardian have shown similar results in other trials. Barrier 1, Paramount and Kuban 86 need to be tested in a location with high ring nematode pressure to confirm results in this trial. Julior, Adesoto and Cadaman appear to be highly susceptible to root lesion (*Pratylenchus vulnus*).

Tree Growth and Yield

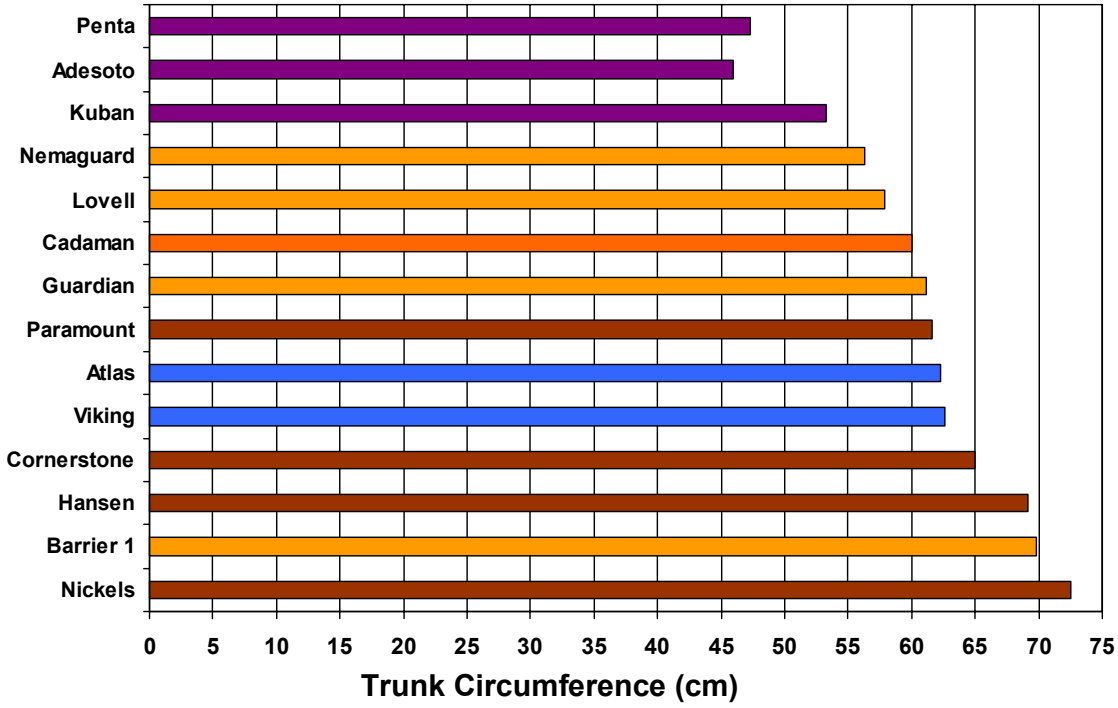
Even though this orchard was not fumigated prior to planting, growth has been good to excellent for most of the rootstocks. The largest trees are on Empyrean #1 and the three peach / almond hybrid rootstocks (Nickels, Hansen 536, and Cornerstone). Trees on the plum rootstocks (Empyrean #2, Empyrean 101 and Julior) are very small and may not be well suited for flood irrigation in a sandy loam soil. Trees on Empyrean #2 showed mild signs of incompatibility in 2006 but seemed to grow out of it in 2007. P30-135 was removed from the trial after the first year due to serious incompatibility problems and replaced with Krymsk 86 (a.k.a. Kuban 86). All plum rootstocks, particularly Empyrean 101, sucker considerably more than Nemaguard.

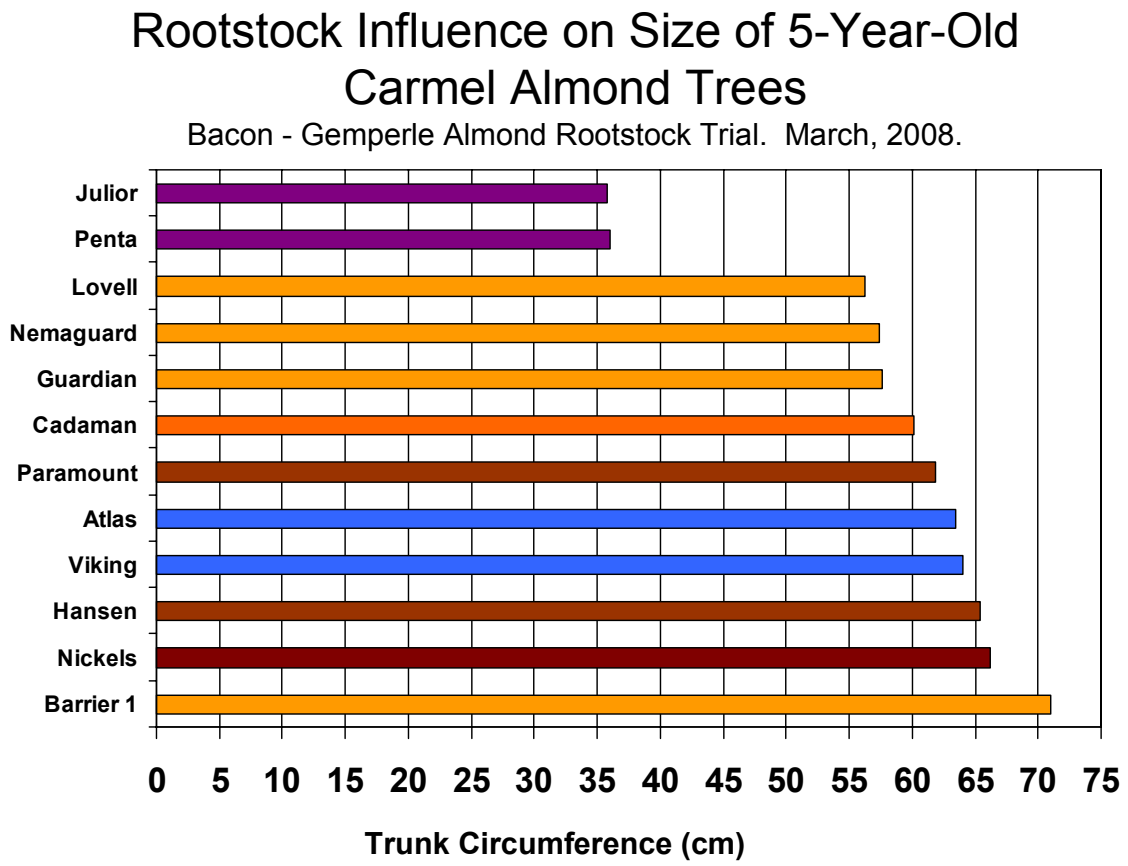
Table 2. Rootstock Host Suitability to Ring (*Mesocriconema xenoplax*) and Root Lesion (*Pratylenchus vulnus*) Nematodes on Young Almond Trees. February, 2007 & 2008.

Rootstock	Ring		Root Lesion	
	4th leaf	5th leaf	4th leaf	5th leaf
Hansen 536	**424**	**183**	2	2
Nickels	**353**	**446**	5	2
Cornerstone	**223**	**439**	7	3
Julior	**288**	10	**34**	**70**
Empyrean #101 (a.k.a. Adesoto)	**104**	30	**33**	**75**
Avimag (a.k.a. Cadaman)	42	31	**39**	**53**
Nemaguard	17	25	0.4	3
Lovell	9	10	4	21
Empyrean #2 (a.k.a. Penta)	6	71	9	15
Atlas	6	26	9	7
Krymsk 86 (a.k.a. Kuban 86)	2	0	1	1
Paramount (a.k.a. GF 677)	0	1	10	0
Guardian SC-17	0	0.4	0	3
Empyrean #1 (a.k.a. Barrier 1)	0	0	12	13
Viking	0	0	6	4

Rootstock Influence on Size of 5-Year-Old Nonpareil Almond Trees

Gemperle - Bacon Almond Rootstock Trial, March 2008





Yields for most rootstocks were excellent for 5th-leaf trees (see Table 3 below). As expected, the most vigorous rootstocks (the largest trees) tended to be the highest yielding because the canopy is still developing in this young orchard. The highest yielding rootstocks for Nonpareil were Empyrean #1 and Hansen 536, respectively. The highest yielding rootstocks for the Carmel variety were Nickels, Atlas, Hansen and Paramount, respectively. Carmel on Atlas had yields similar to the peach / almond hybrid rootstocks even though trees on Atlas are not as large. Previous UC rootstock trials have indicated that Atlas may have relatively high yield efficiency. As trees in this trial get older and fill the space in the orchard, high vigor may become less important than yield efficiency (pounds of nuts per area of tree canopy). In fact, extreme vigor in a mature almond orchard may be undesirable. Lower yields on some less vigorous rootstocks could be compensated for by planting these trees more densely in an orchard. It is unlikely that trees on the plum rootstocks (Julior, Empyrean 101 and Empyrean #2) could achieve yields equivalent to the highest yielding rootstocks in this trial because they are so small, especially for the Carmel variety. Empyrean 101 and Empyrean #2 also had the smallest kernel size for the Nonpareil variety. There was no difference in kernel size among all rootstocks for the Carmel variety. Rootstock influence on double or shriveled kernels was unclear.

Table 3. Yield Parameters of Fifth-leaf Almond Trees on Various Rootstocks in a Non-fumigated Replant Site. 2007.
Bacon / Gemperle Rootstock Trial. Ceres, CA

	Nonpareil		Carmel	
	Yield per Acre* (lb)	**Weight per 100 kernels (g)**	**Yield per Acre* (lb)**	**Weight per 100 kernels (g)**
Empyrean #1	3191 a	110.3 a	3409**	122.0**
Hansen 536	2896 ab	109.9 a	3814 ab	117.0 a
Cornerstone	2777 bc	109.5 a	--	--
Nemaguard	2650 bcd	107.1 ab	2797 c	114.2 a
Nickels	2600 bcd	112.5 a	4261 a	122.2 a
Avimag	2586 bcd	107.6 ab	2947 c	122.6 a
Atlas	2512 bcd	106.8 ab	3827 ab	122.2 a
Lovell	2488 bcd	106.8 ab	2670 c	120.0 a
Paramount	2460**	107.9**	3684 ab	121.6 a
Viking	2408 cd	107.2 ab	2795 c	118.0 a
Guardian	2272 d	109.4 a	3022 bc	118.4 a
Empryean #2	1288 e	101.8 bc	630**	126.2**
Empyrean 101	1032 e	98.9 c	--	--
Julior**	--	--	747**	121.4**
Krymsk 86** **(fourth-leaf)**	1143**	109.0 a	--	--

*Yield per acre calculation based on a spacing of 17' x 21' (122 trees per acre).
**Observational rootstocks are not replicated in the trial. Krymsk 86 is fully replicated but trees are one year younger than the rest of the trial.

B. Alternative Rootstocks in Butte County: evaluate variety compatibility, Field Performance, and Tolerance of Alternative Rootstocks for Almond to the Oak Root Fungus, *Armillaria Mellea*.

Project Leader: J. H. Connell

Project Cooperators: CSU Chico Farm
G&N Creekside Farms
Sam Lewis & Son
Brouwer Orchards

Objective:

Evaluate variety compatibility with alternative rootstocks, assess their field performance, and assess the tolerance of these alternative rootstocks to oak root fungus.

Materials and Methods:

Oak root fungus spots were identified in several commercial orchards in the Chico area and replants on alternative rootstocks were planted in those spots to gauge both their compatibility with almond and their ultimate survival when exposed to the fungus. Fowler nursery provided 'Nonpareil' and 'Carmel' on 'Ishtara' in 2002 to evaluate compatibility and oak root fungus resistance at the CSUC Farm. Additional alternative rootstock trees were planted in this and other oak root fungus spots in Butte County in spring 2003. These included 'Nonpareil', 'Sonora', and 'Carmel' on 'Hiawatha' (a plum rootstock, *Prunus besseyi x P. salicina*), 'Nonpareil' on 'Tetra', and some additional 'Nonpareil' trees on 'Ishtara'. In spring 2004 additional 'Nonpareil' trees were planted in oak root fungus spots on the 'Empyrean 101' rootstock. A subjective rating scale from 0 to 4 was used to evaluate tree performance with 0 = tree failing (almost no growth, leaning, dying or dead) and 4 = a very vigorous tree with excellent growth and anchorage. A rating value approximating 2.5 or better is necessary for the tree to be displaying commercially acceptable growth and vigor.

Working with Brouwer Orchards in Durham, Fowler Nursery planted 10 tree plots of 'Ishtara' and Advantage® ('Marianna 2624' with a long 'Padre' interstem) rootstocks in a high pH (>8.0) alkaline spot on heavy clay soil in 2002 while the grower planted 'Marianna 2624' plum to fill in the trouble spot and 'Lovell' peach rootstock throughout the remainder of the orchard. This uniformly planted orchard has afforded the opportunity to quantitatively compare the effects of variety and rootstock on tree growth. Trunk circumference measurements were taken in June 2007 during the orchard's sixth growing season.

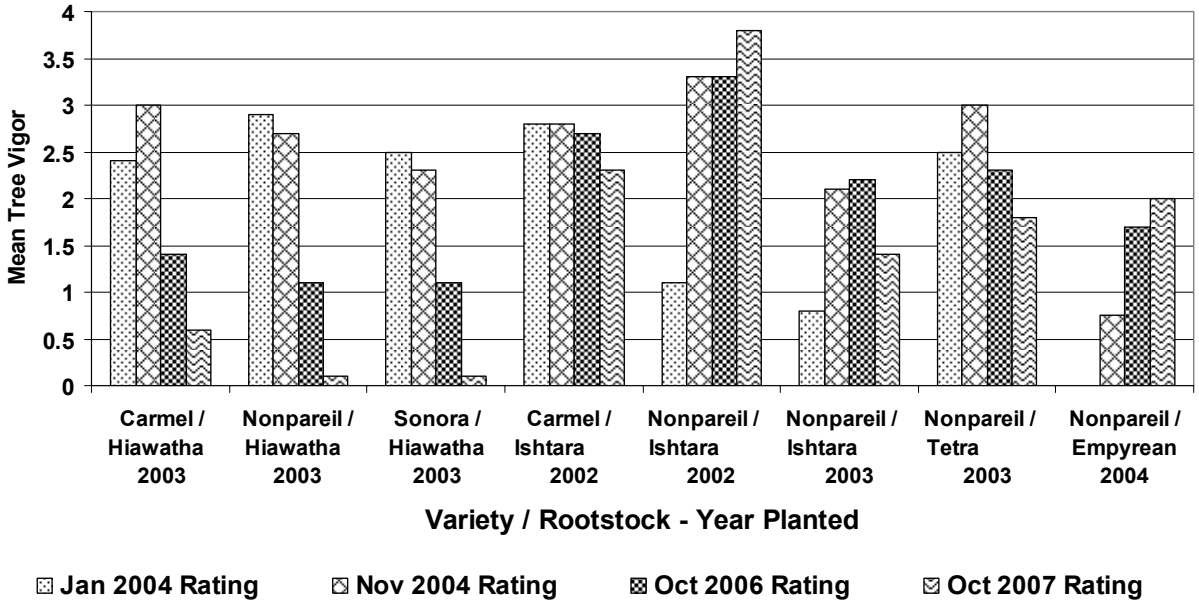
Results and Discussion:

The USDA Agricultural Research Service identified two plum type rootstocks that were possibly compatible with 'Nonpareil'. One of these, 'Deep Purple', proved to be incompatible with almond very quickly. The other rootstock, 'Hiawatha' (*Prunus besseyi x p.salicina*) has shown resistance to root knot and root lesion nematodes in field trials but it's compatibility with almond was uncertain and hence it was planted in two orchards with three varieties used as scions. 'Nonpareil', 'Carmel' and 'Sonora' trees on 'Hiawatha' planted in spring 2003 all grew reasonably well for the first two years in one orchard (fig. 1) but were weak in the other (fig. 2). Following five growing seasons it's clear that 'Hiawatha' has completely failed as a rootstock for almond and I will recommend that our cooperators remove these trees this winter. Although trees on 'Hiawatha' are still growing, nearly all are leaning or have fallen over indicating poor compatibility and a weak root system.

'Carmel' trees planted on 'Ishtara' in spring 2002 grew well from the beginning and have produced small but commercially acceptable trees after six growing seasons. In the 2002 planting, growth of 'Nonpareil' on 'Ishtara' was weak through the 2003 season but improved in 2004 and has remained strong through 2007. 'Nonpareil'

on ‘Ishtara’ planted in 2003 were small weak trees to begin with and have remained weaker in this trial since then (fig. 1).

Figure 1. Tree vigor on alternative rootstocks, CSUC Farm, Butte County.



‘Nonpareil’ trees planted on ‘Tetra’ in 2003 performed better initially at the CSUC farm than at G&N Creekside Farms (figs. 1 & 2). ‘Tetra’ rootstock produced smaller trees whose performance weakened during the 3rd through 5th growing seasons. In addition, one of six trees on ‘Tetra’ succumbed to oak root fungus during the 2007 season. ‘Tetra’ is susceptible to oak root fungus and does not appear acceptable as a rootstock for ‘Nonpareil’ almond.

‘Nonpareil’ trees planted in March 2004 on ‘Empyrean 101’ rootstock in three different orchards have shown variable performance. After four growing seasons this rootstock is producing trees that are small for their age and that have unacceptable shoot growth in two orchards (figs. 1 & 2) although they are improving in one orchard (fig. 1). At G&N Creekside Farms where comparisons with similar aged ‘Aldrich’ on ‘Marianna 2624’ can be made, the trees on Marianna rootstock are vigorous and commercially acceptable (fig. 2). In the third orchard, trees on ‘Empyrean 101’ are growing well and are performing similar to nearby trees on ‘Marianna 2624’ (fig. 3) where both are currently commercially acceptable. Whether almond trees on ‘Empyrean 101’ will last and be commercially acceptable is still an open question but the variable performance of trees on this rootstock is not encouraging. Susceptibility to oak root fungus is still unknown.

Figure 2. Tree vigor on alternative rootstocks, G&N Creekside Farms, Butte County.

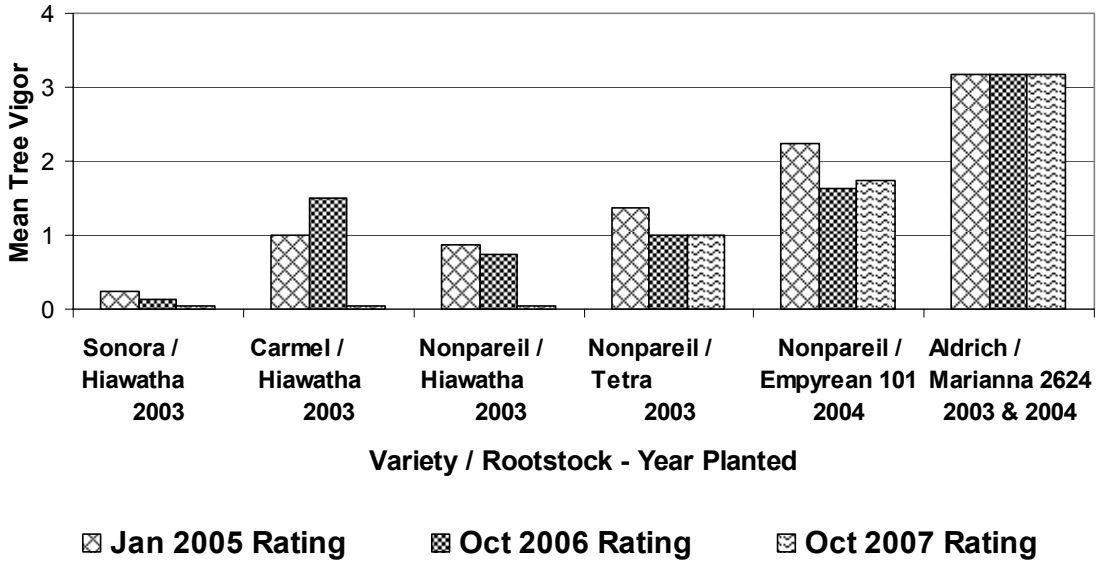
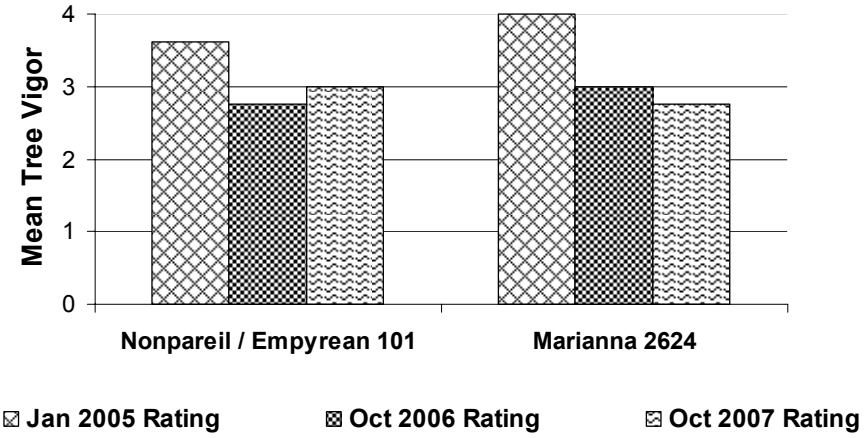


Figure 3. Tree vigor of Nonpareil on Empyrean 101 rootstock planted in March 2004 compared to nearby Marianna 2624 replants, Butte County.

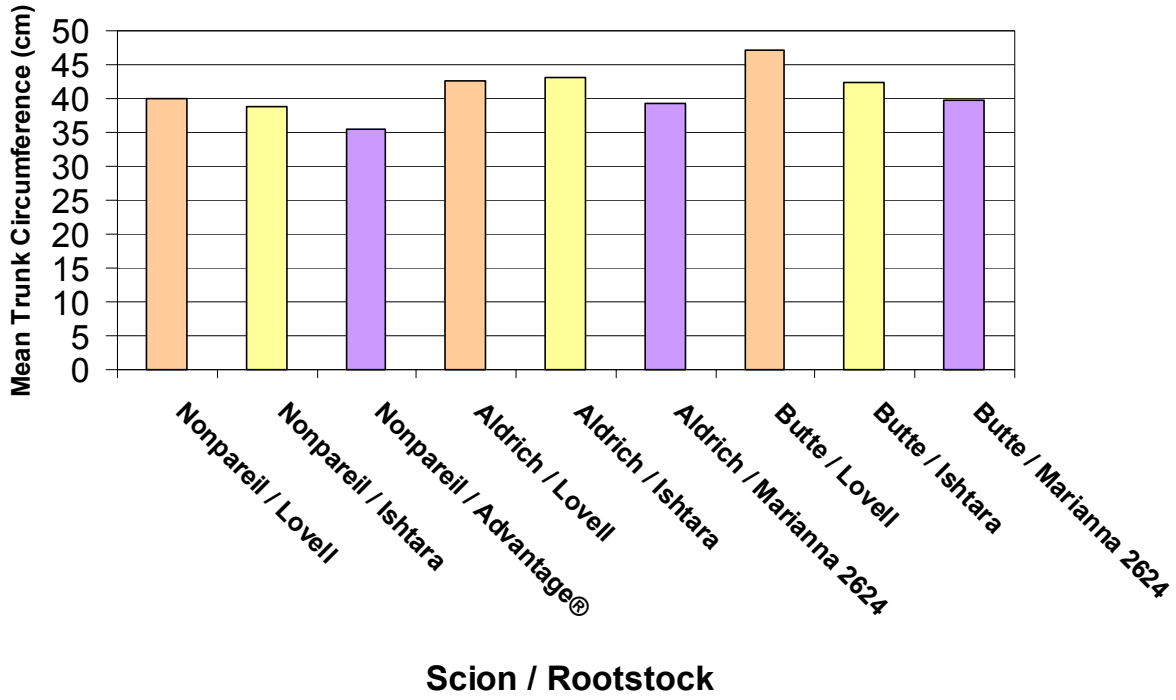


In Brouwer Orchard's observation plots established by Fowler Nursery, we quantitatively compared the effects of variety and rootstock on tree growth through trunk circumference measurements taken during the orchard's sixth growing season in June 2007. When comparing the trunk size of scion varieties 'Nonpareil', 'Aldrich' and 'Butte', 'Butte' is largest in trunk circumference on 'Lovell' peach roots while 'Nonpareil' has the smallest trunk circumference on all three rootstocks (fig. 4). 'Aldrich' is similar in size to 'Butte' on 'Ishtara' and 'Marianna 2624' rootstocks but is intermediate on the 'Lovell' rootstock.

Within each of the varieties, trees on 'Marianna 2624' rootstock were always the smallest in circumference. 'Lovell' rootstock produced the largest trees for both the

'Butte' and 'Nonpareil' varieties while 'Lovell' and 'Ishtara' rootstocks produced similar sized trees of the 'Aldrich' variety (fig. 4). On heavy soil, the 'Ishtara' rootstock appears to be generally competitive with 'Lovell' and produces trees that are more vigorous than trees on 'Marianna 2624'. All three rootstocks held up well on this heavy soil during the extremely wet 2004-2005 winter so differences related to crown or root rots have not yet been observed.

Figure 4. Trunk circumference as influenced by variety and rootstock.



Conclusions:

'Hiawatha' rootstock is incompatible with almond. 'Tetra' rootstock produces unacceptably weak trees and is susceptible to oak root fungus. The performance of the 'Empyrean 101' rootstock is variable and the jury is still out on this one. Some 'Ishtara' rooted trees have successfully completed their 6th growing season in the CSUC Farm's oak root fungus spot. In terms of scion growth and vigor 'Ishtara' is the most promising of these alternative rootstocks. 'Nonpareil' performance on 'Ishtara' has been encouraging although the trees are still young and some concerns were noted in 2007. In a couple of Sacramento Valley 'Ishtara' plantings, strong north winds in late spring blew over a few 'Ishtara' rooted trees. In an orchard known for virulent oak root fungus that can kill 'Marianna 2624' one 'Ishtara' rooted tree was also killed by the fungus.

Whether the two rootstocks 'Empyrean 101' or 'Ishtara' will hold up against oak root fungus in these plots remains to be seen. They are just now reaching the age when their roots are extensive enough to encounter and acquire the disease from old infected roots in the soil profile.

C. Alternative Rootstocks for Almonds

Project Leader: John Edstrom

Project Cooperator: Stan Cutter, Nickels Trust

Objectives:

Trial #1: Evaluate the compatibility and performance of 'Hiawatha' and other plum rootstocks for almond and determine the compatibility of new almond varieties on 'Marianna 2624' ; and, Trial #2 evaluate promising European and other newer rootstocks and interstem options.

Interpretive Summary:

Trial #1: After eight years of field testing, 'Avalon' and 'Winters' appear compatible with M2624 rootstock while 'Plateau' is not. Some 'Plateau' trees have died while others show gumming at the graft union and stunted growth indicative of compatibility problems. Some growers have experienced problems with 'Sonora' on M2624, but results in this test show that Sonora can be successful on M2624. Nonpareil trees double budded with 'Padre' as an interstem are growing satisfactorily and continue to show promise for Nonpareil production on M2624 plum rootstock. Yield, tree growth and graft union health of Nonpareil on Hiawatha are acceptable. However, some trees are leaning, indicating weak anchorage for Hiawatha rootstock. Surprisingly, some Nonpareil trees on M2624 are still alive. Notable this season is the higher production of 'Winters' on Marianna plum root (2626 lbs/acre) compared to other varieties on M2624.

Variety/rootstock	Yield lbs/ac	Kernel/oz	Growth Rating	
				Scale
Sonora M2624	2,200	25	4.6	1= very poor
Non/Padre M2624	1,827	26	4.4	2 = poor
Avalon M2624	1,655	27	4.8	3= weak, unacceptable
Mission M2624	1,730	27	4.9	4= mod vigor
Plateau M2624	1,617	23	3.1 D	5= mod good vigor
Winters M2624	2,626	28	4.4	
Nonpareil M2624	699	27	2.8	D= dead trees
Non Hiawatha	2,273	24	4.1	
Butte Hiawatha	1,323	32	3.9	
Non Deep Purple	-	-	all dead	
Mission D Purple	-	-	all dead	

planted in 2000 @ 12' x 22' 165 trees/acre

The performance of various other variety/rootstock combinations is presented in the following table. Yield figures from this small trial seem to show a yield advantage to hybrid rootstocks over Lovell peach for 2007. This drip-irrigated block experienced an abnormally dry rootzone outside the drip wetted zone due to extremely low rainfall. Pre bloom irrigation could only wet the limited drip zone and not the normally wet winter expanded rootzone. Possibly, the more extensive/vigorous hybrid root systems proved an advantage under these conditions. In all previous seasons, under normal winter precipitation of 18 inches, no yield advantage to hybrids has been found.

Variety/rootstock	**Yield lbs/ac**	**Kernels/oz**
Butte/Hansen PA hybrid	2,037	30
Butte/GF 677 PA hybrid	2,385	31
Butte/Lovell	1,746	30
Nonpareil/GF 677 PA hybrid	2,533	24
Nonpareil/Hansen PA hybrid	2,609	25
Nonpareil Lovell	1,847	27
Kochi/Lovell	1,386	25
Durango/Lovell	1,820	25

Planted 2001 @ 18' x 22'
110 trees/acre

Trial #2: The preliminary small scale test of eight alternative rootstocks of European origin planted in 2003 shows highly variable performance. The top four most promising rootstocks, as listed below, were selected for the larger trial. Three selections, AC 952UC1, Pumiselect, and Penta CM7 and have failed completely in this trial.

Rootstock with Nonpareil scions	**Trunk Size (cm circ)**	
Krymsk 86	41.7	
Cadaman (Avimag)	42.3	
Hiawatha	39.8	
Ishtara	40.8	3 dead
Jaspi	35.8	1 dead
AC 952UC1	-	all dead
Pumiselect	-	all dead
Penta CM7	-	all dead

In the 2006 planting, using full rows of each rootstock, Nonpareil scions are growing well on all roots including those with Padre interstems on M2624 or M-40 plum. However, growers must take extra care to prune out competing Padre water sprout growth that can outgrow and overtake the Nonpareil scion. Trunk measurements taken in October show little difference in tree size between the eight rootstocks under evaluation with Nonpareil. The rootstocks include; Padre interstem/M2624, Padre interstem/M-40, Krymsk 86, Empyrean, Hiawatha, Ishtara, Lovell and Nickels P/A hybrid.

Padre interstem shoot requiring summer removal