Field Evaluation of Almond Rootstocks

Project No.: **09-HORT4-Duncan**

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Introduction:

Several new rootstocks, including many from other countries, have recently become available to plant in California. Field trials were initiated in three almond-growing counties to evaluate some of these alternative rootstocks with the following objectives.

Objectives:

Stanislaus County, Roger Duncan (Sections A and B below)
- Evaluate the field performance of Nonpareil and Carmel almonds on sixteen rootstocks in an unfumigated, sandy loam, replant location.
- Evaluate the field performance of potentially oak root rot tolerant rootstocks in a sandy loam soil.

Colusa County, John Edstrom (Section C below)
- Evaluate the compatibility and field performance of new, alternative rootstocks on several almond varieties.
- Evaluate the compatibility and field performance of newer almond varieties on Marianna 2624.

Butte County, Joe Connell (Section D below)
- Evaluate variety compatibility with alternative rootstocks.
- Evaluate alternative rootstocks for tolerance to Armillaria root and crown rot.

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

Roger Duncan, Farm Advisor; UCCE - Stanislaus County
Peter & Christene Bacon and Eric Gemperle; growers

Interpretive Summary:

In January, 2003, a replicated field trial was planted in a commercial almond orchard to test the performance of sixteen rootstocks budded with Nonpareil and Carmel scions in an unfumigated, sandy loam, replant location. 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 is a Hanford sandy loam with no particular chemical or physical soil problems (pH = 6.8; ECe=0.9 dS/m; CEC = 5.2). The orchard spacing is 17' x 21' (122 trees per acre) and is flood irrigated with excellent quality water from the Turlock Irrigation District. 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
Controller 9 (a.k.a. P30-135)	*P. salicina x P. persica*	USDA
Atlas	Complex hybrids containing Nemaguard, Jordanolo almond, plum and apricot	Zaiger Genetics
Viking		Zaiger Genetics

Tree Growth and Yield. Even though this orchard was not fumigated prior to planting, growth has been good to excellent for many of the rootstocks. Calculated yields per acre correlate very strongly with tree size. The most vigorous rootstocks tend to have the highest per acre yields because the canopy has developed more rapidly. Per acre yields of less vigorous rootstocks could be increased early in the life of an orchard by planting trees more densely. The American peach x almond hybrid rootstocks (Nickels, Hansen, Cornerstone) are very large trees and tend to have the highest yields (**Figure 1**

& Table 2). The Carmel variety particularly benefits from being on a vigorous rootstock. Carmel yield on Nickels was almost double the Carmel yield on Nemaguard. Trees on the European peach / almond hybrid (Paramount) are a little smaller than the American peach / almond hybrids. The peach rootstocks (Avimag, Nemaguard, Guardian and Lovell) are all very similar in size and have similar yields. Of these four peach rootstocks, Avimag is slightly larger and Lovell is slightly smaller than the others. Empyrean 1, although it is a peach rootstock, has vigor and yields more comparable to the peach x almond hybrids.

Trees on the plum rootstocks (Empyrean 2, Empyrean 101 and Julior) are very small and may not be well suited for a sandy loam soil, especially under flood irrigation. They probably would have significantly lower yields than the peach x almond hybrid rootstocks even if they were planted very densely. Krymsk 86, a peach x plum hybrid, appears to be slightly less vigorous than Lovell under these growing conditions. Kernel sizes were not statistically different among rootstocks this year. In previous years, the plum rootstocks had the smallest kernels and peach x almond hybrids the largest. To date, we have seen no bacterial canker in the test orchard.

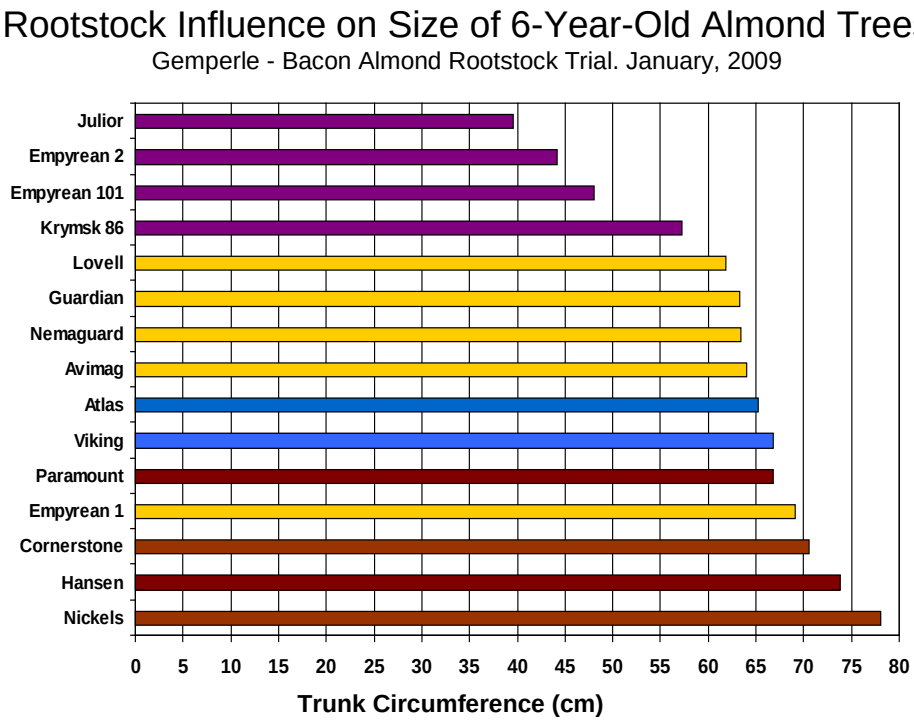


Figure 1

Table 2. Yield of Seventh-leaf Almond Trees in a Non-fumigated Replant Site. Bacon / Gemperle Rootstock Trial, 2009. Ceres, CA				
	Nonpareil		**Carmel**	
	Yield per Acre* (lb)	**Kernels per oz**	**Yield per Acre* (lb)**	**Kernels per oz**
Paramount	--	--	4156 a	21.0
Hansen 536	4083 a	23.4	3841 ab	22.2
Nickels	4075 a	22.7	4046 ab	21.1
Cornerstone	3949 a	23.6	--	--
Atlas	3333 b	24.6	3509 ab	20.2
Empyrean 1	3285 b	23.9	4155**	18.5**
Avimag	3127 b	24.7	3452 ab	21.7
Viking	3110 b	25.9	3112 bc	22.2
Nemaguard	3100 b	25.5	2182 c	19.5
Guardian	3081 b	25.4	2481 c	22.0
Lovell	2793 b	25.2	2307 c	21.2
Krymsk 86** **(sixth-leaf)**	2159 c	24.1	--	--
Empyrean 101	1537 d	24.0	--	--
Empyrean 2	1392 d	24.4	--	--
Julior	--	--	--	--

* Yield per acre calculation based on a spacing of 17' x 21' (122 trees per acre).

** Observational rootstocks are not fully replicated in the trial. Krymsk 86 is replicated but many of the trees are one year younger than the rest of the trial.

B. Field Evaluation of Almond Rootstocks Potentially Tolerant to Oak Root Rot in a Flood Irrigated, Sandy Loam Soil

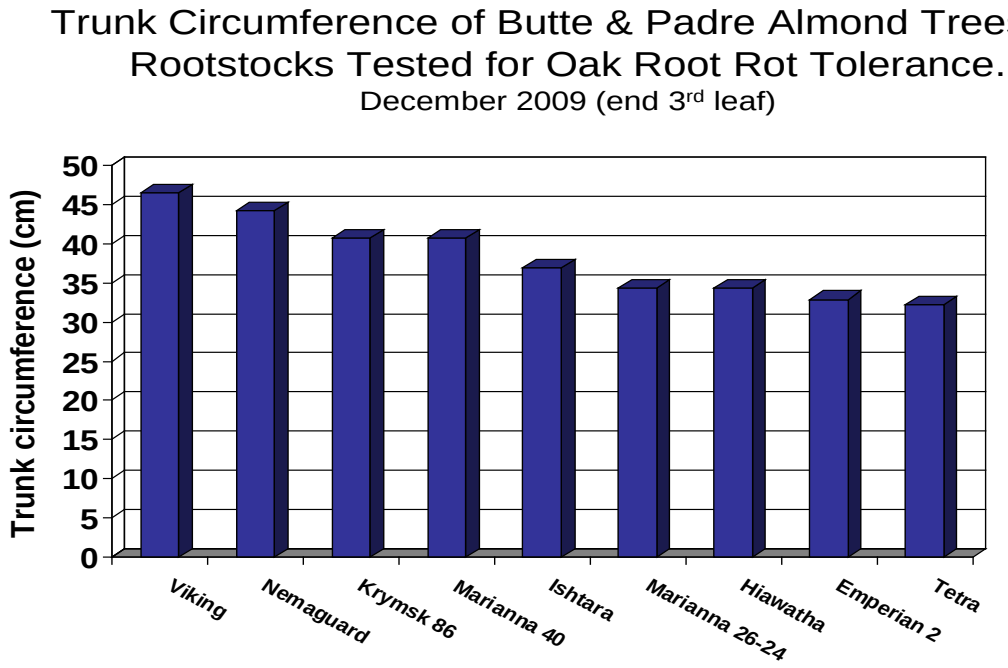
Roger Duncan, Farm Advisor; UCCE - Stanislaus County

Armillaria mellea, the fungus that causes oak root rot, is often most severe in heavy clay soils. However, many North San Joaquin Valley orchards growing in sandy loam soils are also infested with *Armillaria mellea*. Most almond rootstocks thought to be tolerant to oak root rot are plum or have a significant amount of plum in their parentage. In general, plum rootstocks do not perform well in flood irrigated, sandy San Joaquin Valley soils because of their low soil moisture holding capacity and the presence of pathogenic nematodes.

A replicated trial was established in 2007 to monitor the performance of eight rootstocks with plum parentage with the hope that one or more may prove to be tolerant to oak root rot. One year prior to planting the trial, an orchard infested with *Armillaria mellea* was removed. In the fall prior to planting the trial, the soil was treated with Vapam. In January, 2007, the trial including the rootstocks Empyrean 2 (a.k.a. Penta), Hiawatha, Ishtara, Krymsk 86, Marianna 26-24, Marianna 40, Nemaguard, Tetra and Viking was planted. The scion varieties are Butte and Padre.

Results:

All rootstocks grew adequately through the third leaf. Trees on Viking and Nemaguard were the largest while trees on Tetra, and Empyrean 2 were the smallest. Trees on Marianna 40 are larger than trees on Marianna 26-24 and have no root suckers. So far we have had no problem with trees on Ishtara or Hiawatha leaning excessively or falling over as has been reported in previous trials in the Sacramento Valley. In the spring of 2010 (early 4th leaf), two Butte trees on Marianna 26-24 showed signs of union mild etch. These signs of partial incompatibility had faded by mid summer. No signs of oak root rot have appeared yet in this trial.



C. Alternative Rootstocks for Almonds in Colusa County

John Edstrom, UCCE - Colusa County
Stan Cutter**,** Leslie J**.** Nickels Trust

Objectives:

1) Continue the long-term evaluation of seven commercially available rootstocks for Nonpareil yield and other important characteristics.
2) Evaluate the compatibility of Krymsk 86, Ishtara, Hiawatha and other plum rootstock combinations for Nonpareil; study the compatibility of newer almond varieties on Marianna 2624 plum.
3) Evaluate the field performance of four promising experimental rootstocks; Krymsk 86, Empyrean, Hiawatha and Ishtara for use with Nonpareil.

Interpretive Summary:

1) Nonpareil production in this 1997 planting is approaching its maximum potential as most tree canopies have nearly filled their 22 x 24 ft spacing. The peach/almond hybrid selections **Nickels, Hansens 536** and **Brights** have filled their space almost completely while the peach rootstocks **Nemaguard** and **Lovell** and the mixed hybrid rootstocks, **Atlas** and **Viking** have 1-2 feet more space to fill. As a result, these yields are skewed in favor of the larger trees. Given more time the smaller trees may catch-up and show a more commercial per acre yield comparison with the PA hybrids. Yields for 2009, shown in **Table 1** below, are comparable to last year's record production and generally show the higher production from the larger P/A hybrid trees and lower from peach, Atlas and Viking. Nonpareil kernel sizes 22-23/oz was not significantly different between the rootstocks. Of concern is the increasing problem of Phytophthora root/crown rot on some PA hybrid trees. Despite the use of water stream deflectors, micro-sprinkler irrigation sporadically wets the lower trunks of many trees. This condition combined with efforts to meet Etc and maintain deep soil moisture has made these trees more vulnerable to root rot given this clay layered soil. This problem again points to the high susceptibility of peach almond hybrid rootstocks to soil fungi and "wet-feet". Trees were planted on small mounds in this test so most surface water drains away from crowns; however, current local practices include taller berms that further elevate crowns and may improve drainage. This block has not lost many trees to wind and interestingly, tree productivity is quite good in spite of high crown gall infection rates as reported last year.

Table 1. 2009 Yield

Rootstock	Yield lbs/ac	Kernels/oz
Lovell	2,672a	21
Viking	2,909a	22
Atlas	2,938a	22
Nemaguard	2,959a	22
Brights	3,719 b	22
Hansen 536	3,954 b	22
Nickels	3,787 b	22 ns

Nonpareil scions, average of 64 trees. Tukeys alpha = 0.05

2) A second rootstock test planted in 2000 has some of the oldest Nonpareil/**Krymsk 86** trees in the industry. These trees were from some of the first California efforts to propagate Krymsk 86 (Kuban 86) and were quite small and spindly at the time of planting. Tree growth in this group of seven trees is less than optimal and not up to the standard of our more recent evaluations. Despite this, all Krymsk rooted trees survived and have developed good Nonpareil canopies. Production for Nonpareil on Krymsk 86 was 2,256 lbs/acre compared to Nonpareil/Lovell at 2,305 lbs/acre. Cadaman, renamed **Avimag** (peach x almond x wild peach) is a little more vigorous in this test and performing quite well yielding 2,151 lbs/acre. Another selection,

Jaspi is performing poorly while **AC952UC1, Penta CM7** and **Pumiselect** have not survived.

A nearby planting is evaluating the compatibility of newer almond varieties on Marianna 2624 plum. Evaluations have shown noticeable differences between varieties in tree vigor, union abnormalities and crop yield. However, yield results from this planting are not representative of these varieties and are not presented. This trial covers only a single row that has become heavily shaded by adjacent older trees and is not producing up to its potential. However, ten years of evaluation suggest that the main factors that determine rootstock compatibility; tree growth, union condition, suckering, and fall leaf retention all suggest that '**Avalon'** and **'Winters'** are compatible with Marianna 2624 rootstock. The performance of **'Plateau'** indicates it is not compatible.

3) The 2006 planting has shown obvious differences between Nonpareil scion growths grafted onto the eight rootstocks. The trunk measurements shown in **Table 2** generally reflect tree size except for those with Padre Interstem. The high vigor/large girth of the Padre interstem misrepresent the actual size of the canopy as seen in the following photos of Non/Padre/M40 and Non/Lovell. Of special interest to the industry is the performance of Nonpareil directly on Krymsk 86, a peach x plum hybrid from Russia. (see photo) This selection may become a replacement for M2624 and possibly Lovell if continued evaluations confirm the traits seen during the 8 years of testing in the 2000 trial, 4 years evaluation in this test and many other University and grower tests throughout the state. Unlike other plum type rootstocks, Krymsk 86 shows good vigor similar to Lovell under local soil conditions and is reported to have better anchorage (a weakness in peach). Other desirable characteristics identified include very low suckering and some tolerance to wet/heavy soils. Preliminary yield figures as seen here and elsewhere show Krymsk production similar to Lovell. However, more time is needed to fully evaluate this promising rootstock. The primary weakness of Krymsk 86 is its susceptibility to root knot nematode. Other problems may show up as Krymsk 86 is planted in varying growing conditions. Of particular importance is potential tolerance to oak root fungus, high salt and excess boron. These traits have not yet been evaluated.

   Another new plum rootstock, **Empyrean 2** is also showing good production and vigor compared to Lovell, but little additional Information is available. **Hiawatha** again has performed well initially in a test orchard, however poor anchorage has been found in many other locations. A dramatic development in this rootstock trial this year is the very poor performance of both interstem combinations. Nonpareil with a Padre interstem grafted to either M-2624 or M-40 has declined in both vigor and production. Foliage development was delayed and of poor color resulting in a very thin canopy compared to the other items (see photo, **Figure 1**). **Table 2** shows the yields of this 4th leaf non-replicated test.

Figure 1.

Nonpareil-Lovell

Nonpareil/Krymsk 86

Nonpareil/Padre/M-40

Table 2. 4th leaf Nonpareil Yields on Eight Rootstocks, 2009

Rootstock	yield lbs/ac	kernels/oz	trunk circ. (cm)
Ishtara	1,553	25	34.2
Lovell	1,482	23	40.2
Krymsk 86	1,339	24	39.8
Nickels Hyb	1,664	22	44.3
Padre/M2624	696	26	39.6
Padre/M-40	526	25	38.1
Hiawatha	1,341	22	41.3
Empyrean 2	1,363	24	40.1

Nonpareil scions - averages of 18 trees each except Padre/M2624 & Lovell -36 trees.

D. Alternative Rootstocks in Butte County: evaluate variety compatibility, field performance, and tolerance of alternative rootstocks for almond to the oak root fungus, *Armillaria mellea*.

J. H. Connell, Farm Advisor, UCCE – Butte County
Sam Lewis & Son, Brouwer Orchards, Almont Orchards

Objective:

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

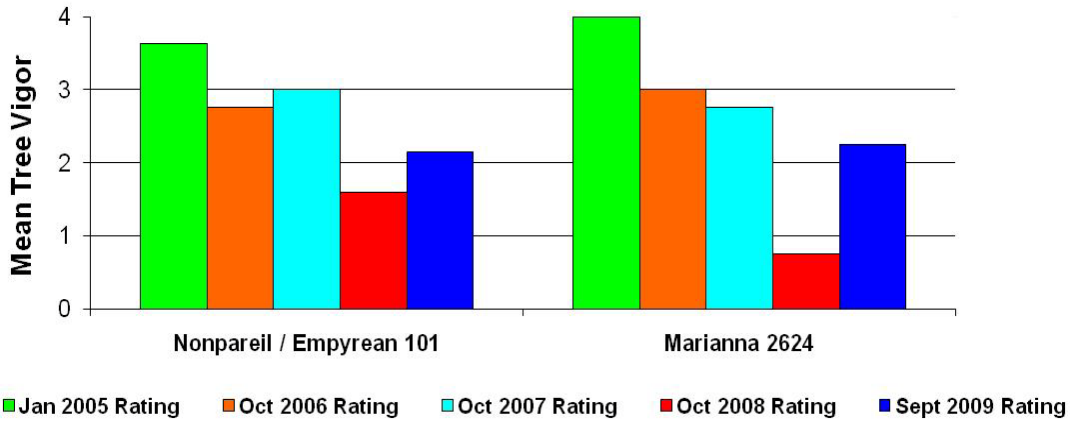
Materials and Methods:

'Empyrean 101' and 'Marianna 2624' are being evaluated in an oak root fungus spot for 'Nonpareil' scion compatibility and tolerance to oak root fungus. Rootstocks 'Ishtara', 'Lovell' peach, 'Marianna 2624', and Advantage® ('Marianna 2624' with a long 'Padre' interstem) planted on a high pH heavy clay soil are compared regarding effects of variety and rootstock on tree size and anchorage.

Results and Discussion:

Nonpareil scions on the 'Empyrean 101' rootstock have grown well and are similar in vigor to nearby trees on 'Marianna 2624' (**Figure 1**). However, the trees are poorly anchored compared to trees on 'Marianna 2624'. In this commercial orchard one of four 'Marianna 2624' rooted trees were staked while five out of seven 'Empyrean 101' rooted trees required staking. Planted in an oak root fungus spot in 2004 none of these trees have succumbed to *Armillaria* at this point.

Figure 1 Vigor of 'Nonpareil' on 'Empyrean 101' rootstock planted in March 2004 compared to nearby 'Marianna 2624' rooted replants.



Note: In September 2009, one of four Marianna 2624 rooted trees were staked, five of seven Empyrean 101 rooted trees were staked.

On heavy soil, ‘Ishtara’ is competitive with ‘Lovell’ in terms of tree size and it produces more vigorous trees than those on ‘Marianna 2624’ (**Figure 2**). Unfortunately, anchorage is also a problem for ‘Ishtara’ since 3 out of 30 trees were lost in high winds and 2 additional trees are leaning. None of the ‘Lovell’ or ‘Marianna 2624’ rooted trees have been lost although two trees on ‘Lovell’ are also leaning.

Figure 2. 8th Leaf trunk circumference as influenced by variety and rootstock.