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# Field Evaluation of Almond Rootstocks

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**Project No.:** 08-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 possess, 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.

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

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

### Interpretive Summary:

New orchards often struggle with a 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 sandy soil. 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 (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 irrigation district water. Rootstocks and their parentage are listed in **Table 1** below.

<b>Table 1. List of Rootstocks Planted in Almond Replant Trial. Ceres, CA</b>		
<b>Rootstock</b>	<b>Parentage</b>	<b>Origin</b>
Nemaguard	Peach ( <i>P. persica</i> x <i>P. davidiana</i> )	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 ( <i>P. persica</i> x <i>P. davidiana</i> )	France & Hungary
Empyrean #1 (a.k.a. Barrier 1)	Peach ( <i>P. persica</i> x <i>P. davidiana</i> )	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)	<i>P. domestica</i> open pollinated	Rome, Italy
Empyrean #101 (a.k.a. Adesoto)	<i>P. insititia</i>	Zaragoza, Spain
Julior	<i>P. insititia</i> x <i>P. domestica</i>	France
Krymsk 86 (a.k.a. Kuban 86)	<i>P. cerasifera</i> x <i>P. persica</i>	Russia
P30-135 (a.k.a. Controller 9)	<i>P. salicina</i> x <i>P. persica</i>	USDA
Atlas	Complex hybrids possibly containing Nemaguard, Jordanolo almond and flowering plum ( <i>P. blireiana</i> )	Zaiger Genetics
Viking		Zaiger Genetics

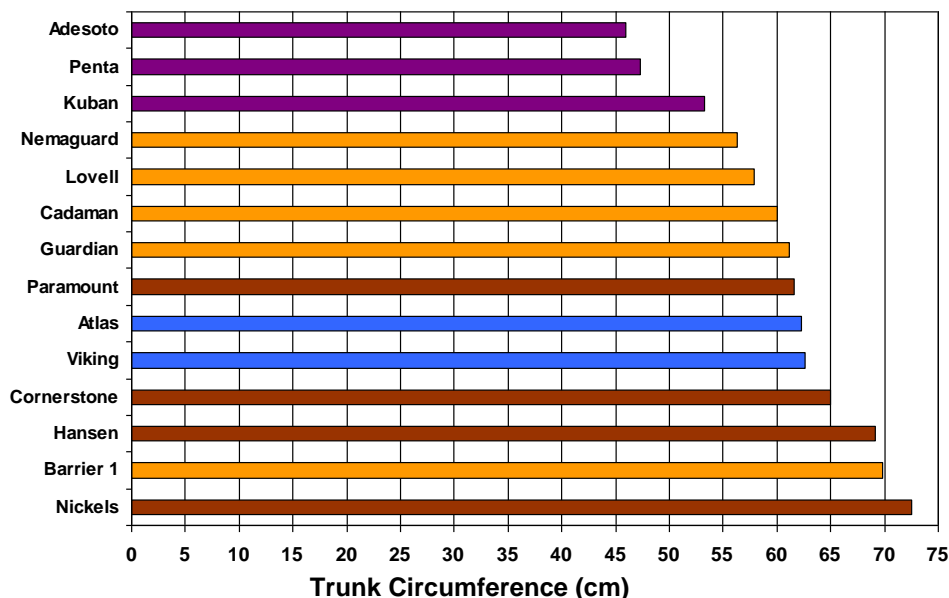
## Tree Growth and Yield

Even though this orchard was not fumigated prior to planting, growth has been good to excellent for 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 a sandy loam soil, especially under flood irrigation. Carmel and Nonpareil trees on Empyrean #2 showed mild signs of incompatibility during the first two growing seasons but seem to have grown out of it. P30-135 was removed from the trial after the first year due to serious incompatibility problems with both varieties and was replaced with Krymsk 86 (a.k.a. Kuban 86).

Yields for most rootstocks were excellent for 6<sup>th</sup>-leaf trees (see **Table 2** below). As expected, the most vigorous rootstocks (the largest trees) tended to be the highest yielding because the canopy has developed more rapidly and filled more space in this young orchard. Empyrean #1 and the peach x almond hybrids (Hansen, Cornerstone and Nickels) had significantly higher yields than all other rootstocks for the Nonpareil variety. The plum rootstocks (Empyrean #2, Julior and Empyrean 101) had very low yields and were approximately 1/3 the yield of the peach x almond hybrids. Plum-rooted trees also had the smallest kernel size. Lower per acre yields on the less vigorous rootstocks could be increased by planting these trees more densely in an orchard. However, 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. There was no rootstock influence on double or shriveled kernels.

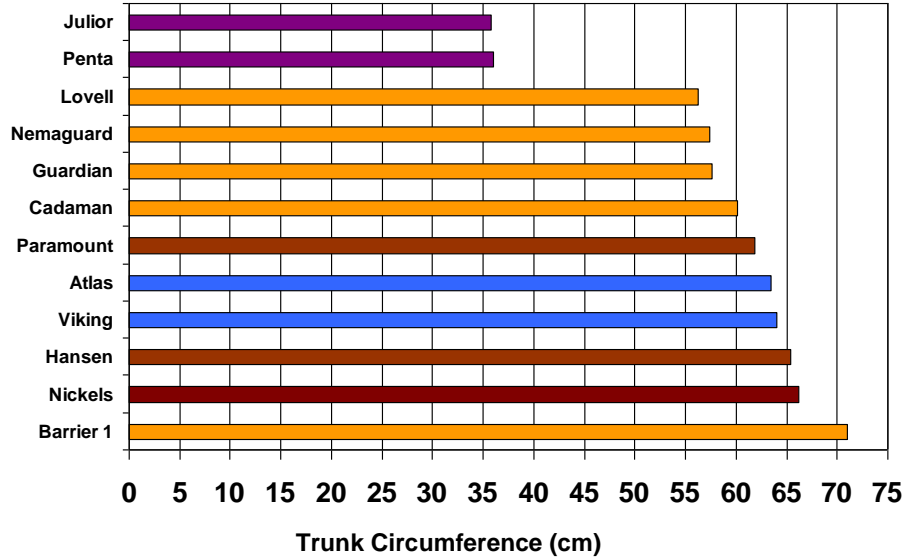
### Rootstock Influence on Size of 5-Year-Old Nonpareil Almond Trees

Gemperle - Bacon Almond Rootstock Trial, March 2008



## Rootstock Influence on Size of 5-Year-Old Carmel Almond Trees

Bacon - Gemperle Almond Rootstock Trial. March, 2008.



**Table 2.** Yield of Sixth-leaf Almond Trees in a Non-fumigated Replant Site. Bacon / Gemperle Rootstock Trial, 2008. Ceres, CA

	Nonpareil		Carmel	
	Yield per Acre* (lb)	Weight per 100 kernels (g)	Yield per Acre* (lb)	Weight per 100 kernels (g)
Empyrean #1	4381 a	108.2 ab	5035**	121.6**
Hansen 536	4353 a	103.8 bc	4857 ab	110.0 abc
Cornerstone	4274 a	105.3 abc	--	--
Nickels	4156 a	110.8 a	5324 a	114.4 a
Paramount	3966 **	107.6 **	4545 abc	115.6 a
Avimag	3401 b	105.2 abc	4208 bcd	116.0 a
Atlas	3385 b	105.6 abc	4590 abc	112.2 ab
Guardian	3266 bc	103.6 bc	3360 de	105.6 bc
Viking	3193 bc	109.2 ab	3751 cde	106.4 bc
Lovell	2944 bcd	108.0 ab	3062 e	111.0 abc
Nemaguard	2719 cd	100.8 cd	3434 de	103.6 c
Krymsk 86** (fifth-leaf)	2468 d	99.3 cde	--	--
Empyrean 101	1733 e	96.8 de	--	--
Julior	--	--	1777**	103.6**
Empyrean #2	1537 e	93.6 e	1216**	106.6**

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

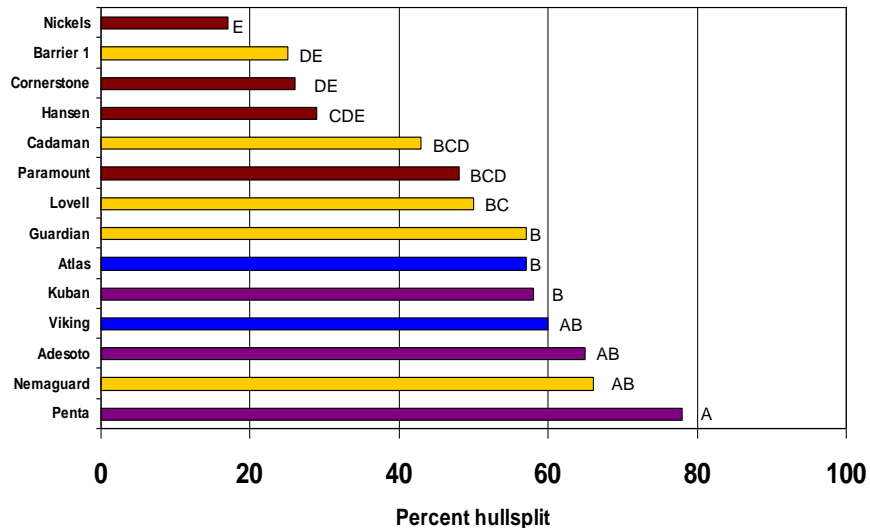
\*\*Observational rootstocks are not fully replicated in the trial. Krymsk 86 is replicated but trees are one year younger than the rest of the trial.

## Effect on hullsplit

Rootstock had a significant effect on timing of hullsplit. Hullsplit on Nickels, Empyrean #1, Cornerstone and Hansen was delayed significantly compared to Nemaguard. This delay in maturity may have implications for navel orangeworm management and other cultural operations.

### Effect of Rootstock on Hullsplit of Nonpareil Almond.

July 30, 2008



## 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 started out low in this trial and remain at low levels except in the most susceptible rootstocks. Hansen, Nickels and Cornerstone (all P/A hybrids) as well as Julior and Adesoto are supporting large numbers of ring nematodes and therefore represent a high risk of developing bacterial canker in canker prone soils (**Table 3**). Viking, Barrier 1, Guardian, Paramount and Kuban 86 continue to host extremely low numbers of ring nematodes. Viking and Guardian have proven to be relatively tolerant of ring nematodes and bacterial canker in other local 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*).

**Table 3.** Almond Rootstock Host Suitability to Ring (*Mesocriconema xenoplax*) and Root Lesion (*Pratylenchus vulnus*) Nematodes. February, 2007 & 2008.

Rootstock	Ring		Root Lesion	
	4 <sup>th</sup> leaf	5 <sup>th</sup> leaf	4 <sup>th</sup> leaf	5 <sup>th</sup> 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

## Alternative Rootstocks for Almonds in Colusa County

John Edstrom, Farm Advisor, 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:

Nonpareil production in this 1997 planting is approaching its maximum potential as most tree canopies have nearly filled their 22 x 24 ft spacing. Trees on the peach x almond (PA) hybrid selections 'Nickels', 'Hansen 536' and Brights have filled their space almost completely while the peach rootstocks Nemaguard and Lovell and complex hybrid rootstocks 'Atlas' and 'Viking' have 1-2 feet more space to fill. As a result, these calculated per acre yields are skewed in favor of the larger trees. Given 2-3 more years the smaller trees may catch-up and show true per acre yield comparisons with the PA

hybrids. Yields and kernel size for 2008, shown in **Figure 1**, generally show the highest production from the larger PA hybrid trees and lower from peach. Kernel sizes ranged from 23/oz for Nickels to 25/oz for most others. Of concern is the increasing problem of *Phytophthora* root/crown rot on some PA hybrid trees. Micro-sprinkler irrigation sporadically wets the lower trunks of many trees and coupled with our efforts to fully meet Etc and maintain deep soil moisture has made these trees more vulnerable to root rot given this clay layered soil. This again points to the high susceptibility of peach almond hybrid rootstocks to soil fungi and wet-feet.

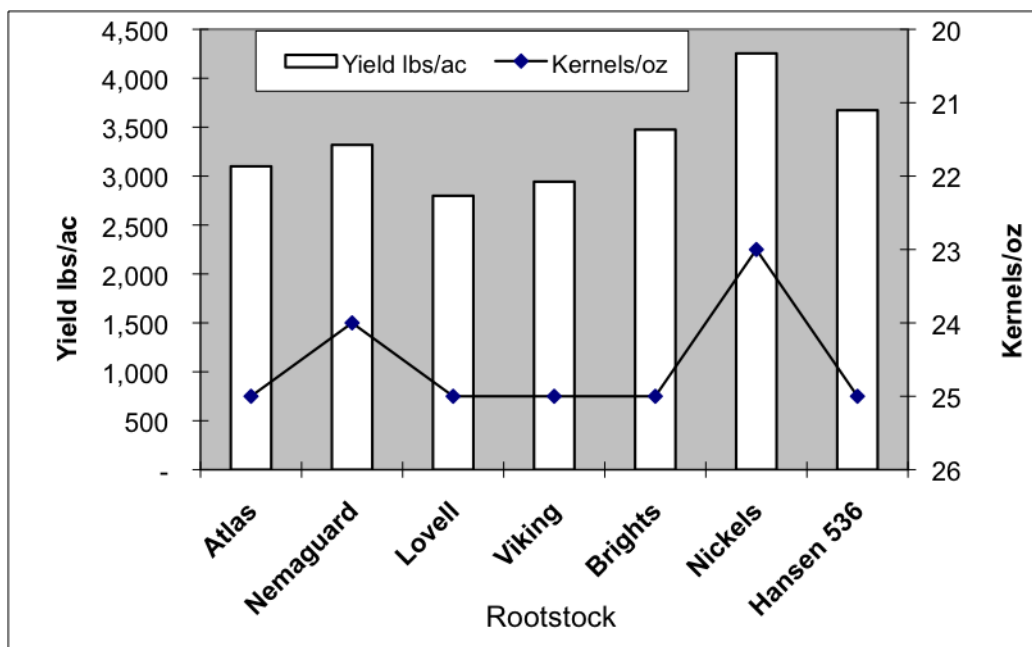
Additionally, all 64 trees of each rootstock were visually rated for gall formations at the soil line from crown gall, *Agrobacterium tumefaciens*. The percentages of trees with galls are given in **Table 1**. A very high incidence (65%) of crown gall was found in Hansen 536, followed by Nickels (37%), Brights (26%), Nemaguard (25%), Lovell (23%), Atlas (11%) and Viking (10%). Most galls were small; sizes ranged from a golf ball up to a soft ball. Generally, the largest trunks had the largest galls. Importantly, the nursery source may have affected the trees propensity for crown gall, as three different nurseries provided the individual rootstocks, i.e. nursery #1 provided Hansen, Lovell and Nemaguard, nursery # 2 provided Brights, and nursery # 3, Atlas and Viking. Interestingly, productivity in this orchard is quite good in spite of high crown gall infection rates.

**Table 1.** 1997 planting, Nonpareil 2008 results

<b>Rootstock</b>	<b>Yield lbs/ac</b>	<b>% Crown gall*</b>	<b>Trunk circ. cm</b>
Lovell	2,799 a	23	77.7 a
Viking	2,943 a	11	80.3 ab
Atlas	3,100 ab	11	75.9 a
Nemaguard	3,319 abc	25	77.2 a
Brights	3,475 abc	26	84.9 bc
Hansen 536	3,673 bc	65	89.1 c
Nickels	4,366 c	37	85.1 bc

\*Percentage of trees showing galls on rootstocks at soil surface-Nonpareil scions, average of 64 trees. Tukeys alpha = 0.05

**Figure 1.** 1997 planting, Nonpareil yields and kernel size for 2008



A second rootstock test planted in 2001 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 below average and not up to the standard of our recent evaluations of Krymsk 86. Despite this, all Krymsk rooted trees survived and have developed good Nonpareil canopies producing 1,623 lbs/acre this season. Cadaman, renamed Avimag (peach x almond x wild peach) is more vigorous and performing quite well yielding 1,965 lbs/acre. Another selection, Jaspi is performing poorly while AC952UC1, Penta CM7 and Pumiselect have not survived.

The 2000 planting evaluating the compatibility of newer almond varieties on Marianna 2624 plum root shows 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, eight years of evaluation suggest that the four main factors that determine rootstock compatibility; tree growth, union condition, suckering, and fall leaf retention all suggest that 'Avalon' and 'Winters' are compatible with M2624 rootstock. The performance of 'Plateau' indicates it is not compatible.

The 2006 planting has shown obvious differences between Nonpareil scion growths on the eight rootstocks. The trunk measurements shown in **Table 2** generally reflect tree size except for Non/Padre/M2624. The high vigor/large girth of the padre interstem misrepresents the actual size of the canopy as seen in the following photo of Non/Padre/M2624 on the left and Non/Lovell on the right. Of special interest to the industry is the performance of Nonpareil directly on Krymsk 86, (**see photo**) a peach x plum hybrid from Russia. This selection may become a replacement for M2624 if



continued evaluations confirm the traits seen during 7 years of testing in the 2000 trial, 3 years in this test and many other tests throughout the state. Unlike other plum type rootstocks, Krymsk 86 shows good vigor similar to Lovell, the local standard peach stock, and is reported to have better anchorage than peach. Other desirable characteristics identified include very low suckering and tolerance to wet/heavy soils. Tree growth in a Butte County orchard shows that Krymsk may have some tolerance to high pH sodic soils. Early yield data show Krymsk production levels are similar to Lovell. However, more time is needed to fully evaluate this promising rootstock. Unknown weaknesses may show up as Krymsk 86 is planted in varying growing conditions.

Another new plum rootstock, Empyrean 2 (**see photo**), is also showing good vigor compared to Lovell, but little additional information is available. Hiawatha plum again has performed well initially in this test orchard, however poor anchorage has been found in many other locations. The Padre/M-40 interstem alternative with Nonpareil scion shows thin canopy development and poor vigor. Tree development is somewhat inferior to the commercial Padre/M-2624 option that is also weak. Test trees are too young to evaluate the reduced suckering potential reported on M40 plum rootstock. **Table 2** shows some early yield and trunk size figures for the selections.



Nonpareil-Padre-M2624



Nonpareil-Lovell



Nonpareil-Krymsk 86

Nonpareil-Empyrean 2

**Table 2.** 2006 planting, Nonpareil results

<b>Rootstock</b>	<b>Yield / plot (lbs)</b>	<b>Kernels / oz</b>	<b>Trunk circumference (cm)</b>
Ishtara	420	24	30.6
Lovell	418	24	30.1
Krymsk 86	388	24	29.3
Nickels	384	22	31.5
Padre / M-2624	336	25	31.9
Padre / M-40	249	24	29.8
Hiawatha	218	25	30.6
Empyrean 2	188	25	29.3

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

### **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

Jim Floyd & Joe Limberg, CSU - Chico Farm

G&N Creekside Farms

Brouwer Orchards

Sam Lewis & Son Orchards

#### **Objective:**

Evaluate variety compatibility with alternative rootstocks, assess their field performance, and assess the tolerance of these alternative rootstocks to oak root fungus or to high pH heavy clay soil.

#### **Materials and Methods:**

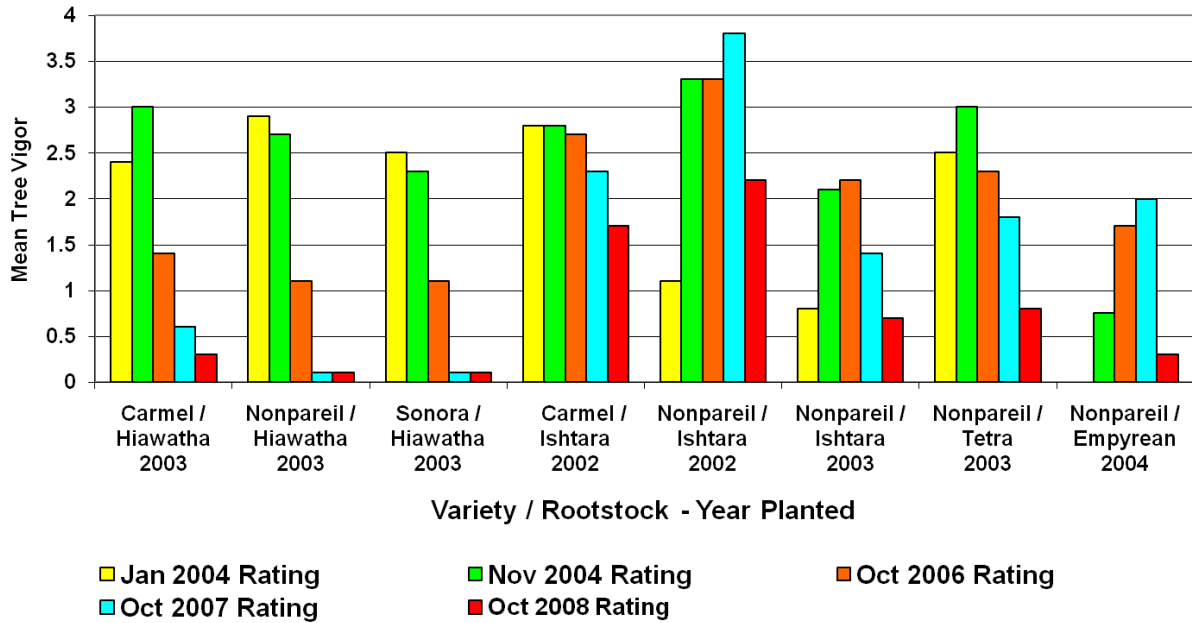
'Hiawatha', 'Tetra', 'Ishtara', 'Empyrean 101', and 'Marianna 2624' have been planted in oak root fungus spots in Butte County and are being evaluated for scion compatibility primarily with 'Nonpareil' almond and for tolerance to oak root fungus. Rootstocks 'Ishtara', 'Lovell' peach, 'Marianna 2624', and Advantage<sup>®</sup> ('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.

#### **Results and Discussion:**

All trees on the 'Hiawatha' rootstock have failed. Some died while others were so poorly anchored they fell over. 'Tetra' rootstock produces unacceptably weak 'Nonpareil' trees and is susceptible to oak root fungus. The 'Empyrean 101' rootstock is also failing (**Figure 1**). Some trees on this rootstock in one orchard are leaning while in two out of three orchards 'Empyrean' rooted trees are unacceptably weak compared to trees on 'Marianna 2624' (**Figure 2**).

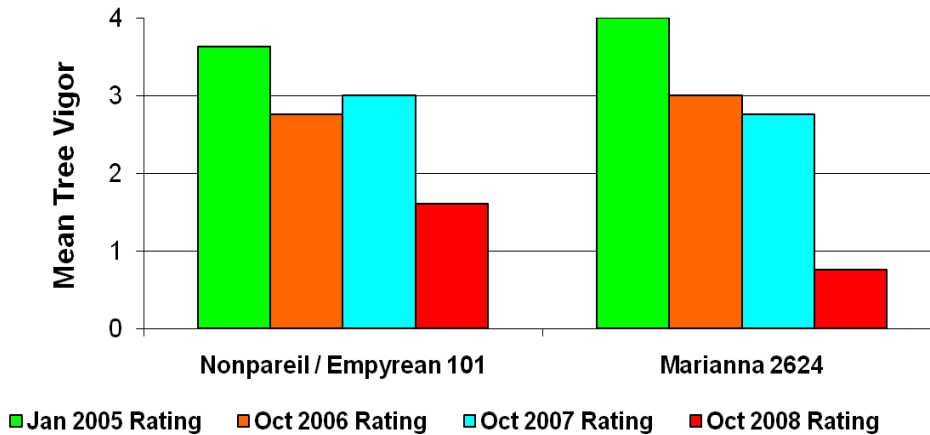
**Figure 1.**

**Tree vigor on alternative rootstocks, CSUC Farm, Butte County.**



**Figure 2.**

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



Some 'Ishtara' rooted trees successfully completed their 7<sup>th</sup> growing season in the CSUC Farm's oak root fungus spot and none have been diseased. In terms of scion growth and vigor 'Ishtara' may still hold promise (**Figure 1**). 'Nonpareil' performance on 'Ishtara' has been encouraging although some concerns were noted in 2007 when strong north winds in late spring blew over a few 'Ishtara'

rooted trees. In an orchard known for virulent oak root fungus that kills 'Marianna 2624' one 'Ishtara' rooted tree was also killed by the fungus (**Figure 3**).

**Figure 3.**



**Nonpareil appears compatible on Ishtara but anchorage and tolerance of oak root fungus are concerns that bear watching.**

On heavy soil, the 'Ishtara' rootstock appears to be generally competitive with 'Lovell' in terms of tree size and it produces trees that are more vigorous than trees on 'Marianna 2624' (**Figure 4**). 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 were not evident. In high winds, 3 out of 30 'Ishtara' trees were lost while none of the 'Lovell' or 'Marianna 2624' rooted trees blew over. All three varieties, Nonpareil, Aldrich, and Butte are smallest when grown on the 'Marianna 2624' rootstock.

Figure 4.

