

# Field Evaluation of Almond Rootstocks

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**Project No.:** 06-HORT2-Duncan

**Project Leader:** Roger Duncan  
UCCE Stanislaus County  
3800 Cornucopia Way # A  
Modesto, CA 95358  
(209) 525-6800  
raduncan@ucdavis.edu

**Project Cooperators:** John Edstrom, UCCE Farm Advisor, Colusa County  
Joe Connell, UCCE Farm Advisor, Butte County

## **Interpretive Summary:**

Almonds are grown throughout the Central Valley of California. Various physical and chemical soil differences exist in this vast area. In addition, there are many nematode and plant pathogen challenges almond growers must overcome. Despite all of these variables, the great majority of almond trees in California are grown on two rootstocks; nemaguard and lovell. Although these two rootstocks work well in many cases, nemaguard and lovell have significant weaknesses including susceptibility to *Armillaria* root rot, various pathogenic nematodes and the replant "disorder". Currently, Marianna 2624 is commonly planted in *Armillaria mellea* infested soils. However this rootstock has a host of problems, including profuse root suckering and incompatibility with some important almond varieties. There is clearly a need to evaluate alternative rootstocks in the almond industry.

Recently, several new rootstocks have been imported from throughout the world. Others have been developed within the U.S. Some of these are reported to perform well in replant situations. Others are reported to be tolerant or resistant to oak root fungus (*Armillaria mellea*). These rootstocks need to be tested for compatibility with common almond varieties and to be challenged under various biotic and abiotic growing conditions in California.

We have just concluded four regional rootstock trials where most of the readily available, commercial rootstocks were tested under various regional challenges. The results of these trials were published in previous Almond Board Proceedings. Three newly established trials, in Stanislaus, Colusa and Butte Counties, will continue to evaluate some of the rootstocks that performed well in the older trials, as well as evaluate several new, alternative rootstocks.

## **Objectives:**

Specifically, these trials will:

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

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

### **Project Leader:**

Roger Duncan  
UCCE Farm Advisor; Stanislaus County

Nathaniel Battig, Ag Technician, Stanislaus County  
Peter Bacon and Christene Gemperle-Bacon, 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. Even after fumigation, the most commonly planted rootstock (nemaguard) is often colonized by ring nematodes and sometimes succumbs to bacterial canker. Many new rootstocks from around the world have recently become available in the U.S., some of which are reported to perform well in replant situations. 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.

Through the fourth-leaf, growth on all but one rootstock has been satisfactory. Most of the peach x almond hybrid rootstocks are very vigorous and therefore tend to have the highest, early yields. However, three out of four of these are also hosting significant numbers of ring nematodes and future problems with bacterial canker is a concern. A peach x Chinese wild peach hybrid rootstock out of Italy called Barrier 1 (Empyrean #1), is also very vigorous and is so far supporting only very low numbers of ring nematode. The four rootstocks of plum heritage are the smallest and also have the lowest early yields. Nonpareil and Carmel both had serious incompatibility issues on the rootstock P30-135 and these have been removed from the trial. Rootstock also had a significant effect on bloom date, with the most vigorous rootstocks tending to bloom the earliest.

## **Objectives:**

To examine several new rootstocks for performance with Nonpareil and Carmel almond scions in a sandy loam, replant location.

## **Materials and Methods:**

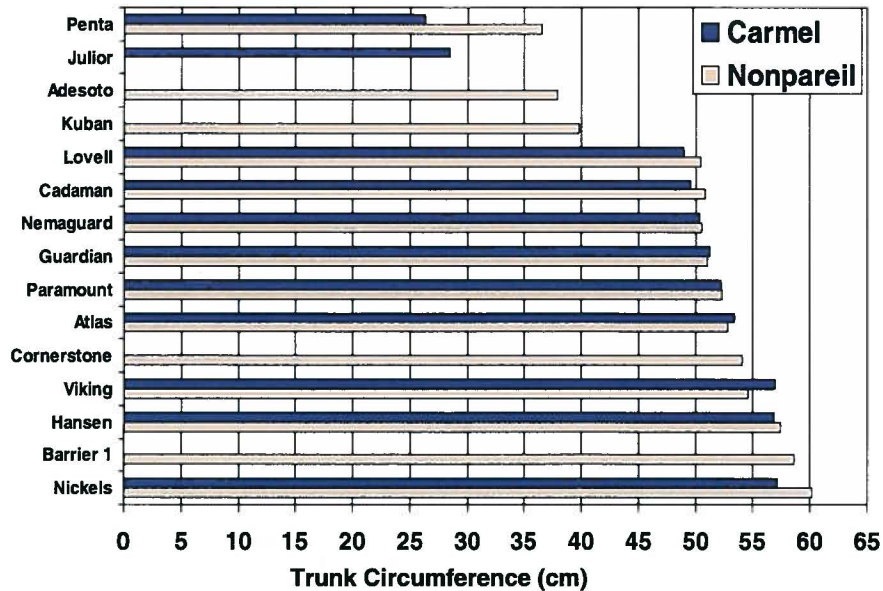
On January 23, 2003, a replicated field trial with Nonpareil and Carmel almond varieties on sixteen rootstocks was planted in a commercial almond orchard. Most of these rootstocks have been reported to perform well in replant situations in various parts of the world. The soil type in the orchard is a Hanford Sandy Loam. An old almond orchard on Nemaguard rootstock was removed the year prior to replanting. Tree sites were backhoed with an excavator in the fall prior to planting but were not fumigated. Table 1 lists the rootstocks included in this flood-irrigated trial.

<b>Rootstock</b>	<b>Parentage</b>	<b>Origin</b>
Nemaguard	Peach	USA
Lovell	Peach	USA
Guardian SC-17	Peach	Clemson University
Empyrean #1 (a.k.a. Barrier 1)	Peach x Chinese wild peach	Venice, Italy
Hansen 536	Peach x almond	UC Davis
Nickels	Peach x almond	UC Davis
Cornerstone	Peach x almond	Burchell Nursery
Paramount (a.k.a. GF 677)	Peach x almond (OP)	France
Avimag (a.k.a. Cadaman)	<i>(Peach x almond) x wild peach</i>	France & Hungary
Empyrean #2 (a.k.a. Penta)	<i>P. domestica</i>	Rome, Italy
Empyrean #101 (a.k.a. Adesoto)	<i>P. insititia</i>	Zaragoza, Spain
Julior	<i>P. insititia x P. domestica</i>	France
Krymsk 86 (a.k.a. Kuban 86)	<i>P. persica x P. cerasifera</i>	Russia
P30-135 (a.k.a. Controller 9)	<i>P. persica x P. salicina</i>	USDA
Atlas	Peach x almond x plum x apricot	Zaiger Genetics
Viking	Peach x almond x plum x apricot	Zaiger Genetics

## **Results and Discussion:**

Trunk circumference data are shown in Figure 1 below. In general, the smallest trees were on the plum rootstocks (Penta, Julior, Adesoto and Kuban). Nickels and Hansen, two peach x almond hybrids, were some of the largest trees. Empyrean #1 (Barrier 1), a domestic peach x Chinese wild peach cross is also very vigorous. Trees on P30-135 grew very poorly. Shoot growth ranged from 1-8 inches during the first season and exhibited symptoms similar to union mild etch. Three trees died. Trees that were exhumed, autoclaved and stripped of their bark showed pitting and grooving at the bud union, a clear indication of compatibility problems. P30-135 should be considered incompatible with almond.

Fig. 1. Rootstock Influence on Size of 4<sup>th</sup>-Leaf Nonpareil and Carmel Almond Trees  
 Gemperle-Bacon Almond Rootstock Trial. October 2006.



**Nematodes:** Soil was sampled to a depth of three feet prior to planting the orchard to determine initial numbers of plant pathogenic nematodes. Even though this orchard was planted only one year after an almond orchard on nemaguard was removed, initial numbers of ring and root lesion nematodes were very low (average of six ring nematodes [*Mesocriconema xenoplax*] per 250 cc of soil and no detectable root lesion [*Pratylenchus vulnus*] nematodes). Soil was sampled again February 1, 2006 to determine rootstock suitability for hosting pathogenic nematodes. After three years, ring nematodes had built to significant numbers on Hansen, Cornerstone, Nickels and Julior (Table 2). The peach x almond hybrid rootstocks of Hansen and Nickels have been shown in past trials to host very high numbers of ring nematodes and have proven to be highly susceptible to bacterial canker. Cornerstone is also a peach x almond hybrid and also looks to be an excellent ring nematode host. Root lesion nematodes are also building in the trial, especially on Julior, Paramount, and Adesoto. Nematode numbers and incidence of bacterial canker will be monitored in this trial over the next few years.

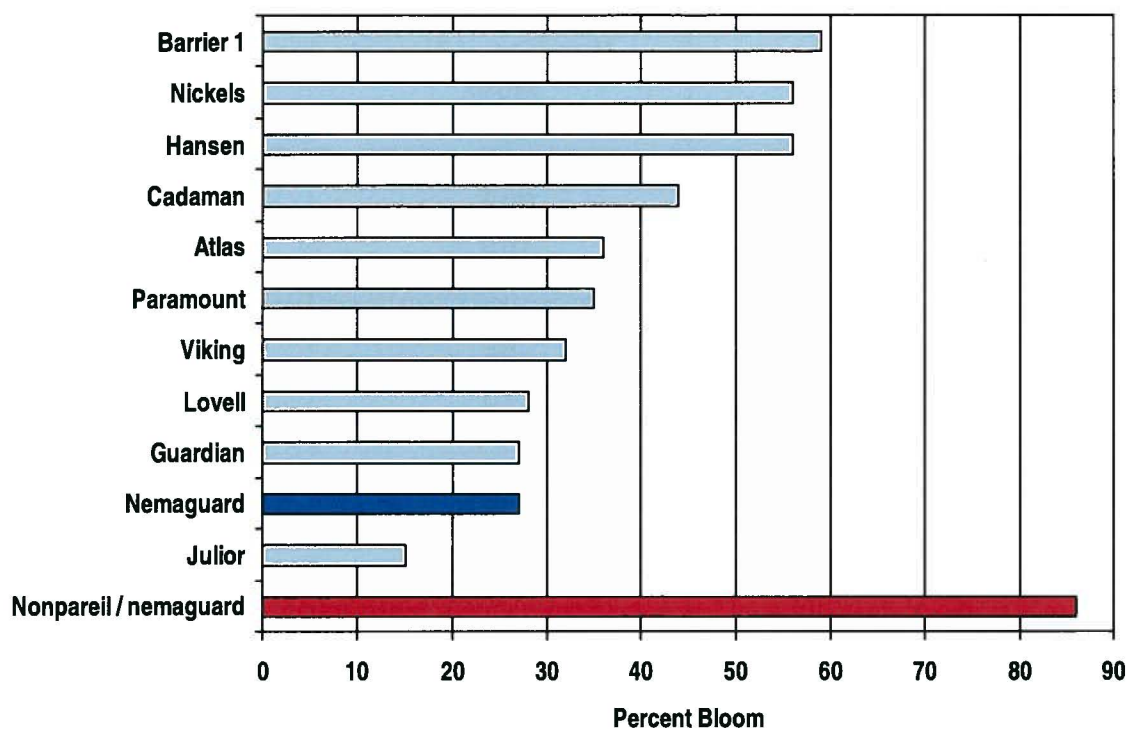
**Table 2. Almond Rootstock Host Suitability to Ring (*Mesocriconema xenoplax*) and Root Lesion (*Pratylenchus vulnus*) Nematodes on Third-Leaf Trees. February, 2006.**

Rootstock	Number of Nematodes per 250 cc of soil	
	Ring	Root Lesion
Hansen 536	280	0.4
Cornerstone	237	2
Nickels	222	0.4
Julior	186	70
Nemaguard	38	2
Avimag (a.k.a. Cadaman)	36	24
Empyrean #2 (a.k.a. Penta)	35	5
Empyrean #101 (a.k.a. Adesoto)	15	44
Empyrean #1 (a.k.a. Barrier 1)	5	20
Guardian SC-17	4	2
Krymsk 86 (a.k.a. Kuban 86)	0.2	0.2
Lovell	0.2	7
Paramount (a.k.a. GF 677)	0	46
Atlas	0	21
Viking	0	4

**Effect on Bloom Date:** In 2006, Carmel bloom was significantly later than Nonpareil bloom in most almond orchards, presumably due to low chill accumulation during the previous winter. In this trial, Carmel trees were evaluated for bloom on February 24, 2006 when Nonpareil trees on nemaguard rootstock were very close to peak bloom. Rootstock had a significant effect on bloom date for Carmel trees in this trial. In general, the most vigorous rootstocks had advanced bloom while the least vigorous trees bloomed the latest (Fig. 2). When Nonpareil trees on nemaguard were at an average of 86% bloom, Carmel trees on nemaguard were at only 27% bloom. Carmel trees on Julior, a weaker plum rootstock, were at only 15% bloom. The most vigorous rootstock, Barrier 1, was at 59% bloom and had the best overlap with the Nonpareil on nemaguard.



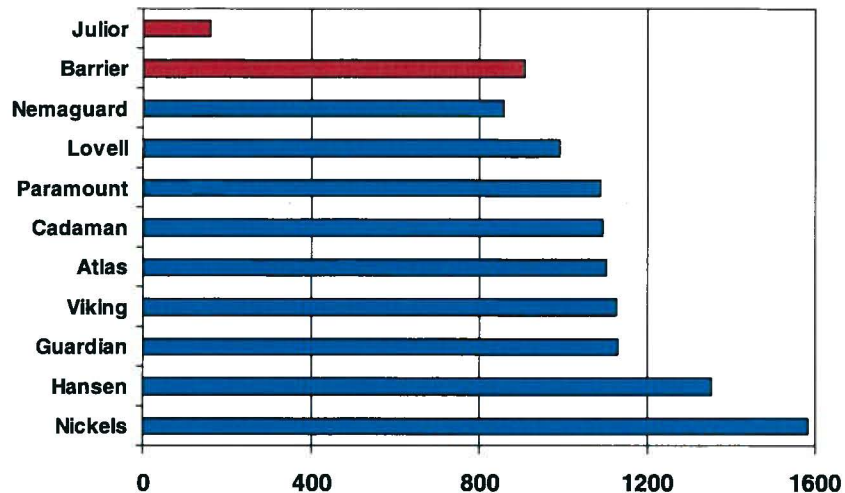
**Fig. 2. Percent Bloom of Carmel Almond as Influenced by Rootstock. February 24, 2006.**



**Yield.** Yield of these 4<sup>th</sup>-leaf trees was heavily influenced by tree size. The most vigorous rootstocks tended to be the highest yielding (Table 3). As the trees get older and fill the space in the orchard, high vigor may become less important than yield efficiency (pounds of nuts per tree canopy area). Lower per tree yields on less vigorous rootstocks could be compensated for by planting these smaller trees more densely in an orchard.

Rootstock	Yield (lb / acre)	% doubles	% blanks
Nickels	684 A	1.2	9.2
Empyrean #1 (a.k.a. Barrier 1)	669 A	1.4	9.2
Hansen 536	642 A	3.2	4.8
Avimag (a.k.a. Cadaman)	617 A	2.0	8.0
Atlas	599 AB	1.0	10.6
Lovell	569 AB	1.6	5.6
Viking	555 AB	1.2	7.6
Cornerstone	553 AB	1.6	11.6
Guardian SC-17	511 AB	1.2	8.8
Nemaguard	469 AB	1.0	7.6
Adesoto	369 B	1.2	4.0

## Yield of 4<sup>th</sup>-Leaf Carmel Almond Trees on Various Rootstocks. 2006



Alternative Rootstocks in Butte County: evaluate the compatibility and field performance of 'Hiawatha' and other plum rootstocks for almond and evaluate their resistance to the oak root fungus, *Armillaria mellea*

**Project Leader:** J. H. Connell

**Project Cooperators:** CSU Chico Farm  
G&N Creekside Farms  
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.

### **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 = a very weak tree with almost no growth 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.

### **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 its compatibility with almond was uncertain and hence it was planted in two orchards with three varieties used as scions. 'Nonpareil', 'Carmel' and 'Sonora' trees planted on 'Hiawatha' 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 four growing seasons at the October 2006 rating, this rootstock failed to produce commercially acceptable trees in both orchards. Trees on 'Hiawatha' are small, weak growing, and poorly anchored. Unfortunately, almond is incompatible on the 'Hiawatha' rootstock.

'Carmel' trees planted on 'Ishtara' in spring 2002 grew well from the beginning and have produced small but commercially acceptable trees after five 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 2006. 'Nonpareil' planted on 'Ishtara' in 2003 started out as small trees and made weak growth in 2003 but improved in 2004 and have continued to improve since then (fig. 1).

'Nonpareil' trees planted on 'Tetra' in 2003 performed better at the CSUC farm than at G&N Creekside Farms (figs. 1 & 2). 'Tetra' appears to produce smaller growing trees whose performance has weakened during the 3<sup>rd</sup> and 4<sup>th</sup> growing seasons. Unless something changes, 'Tetra' is not likely to be acceptable as a rootstock for almond.



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

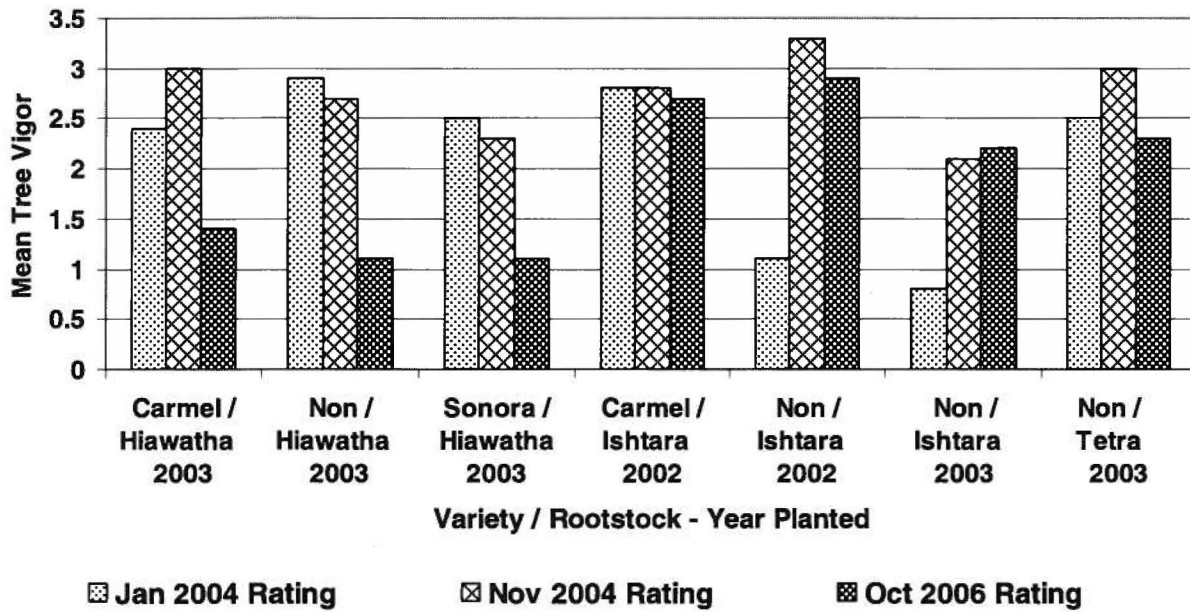
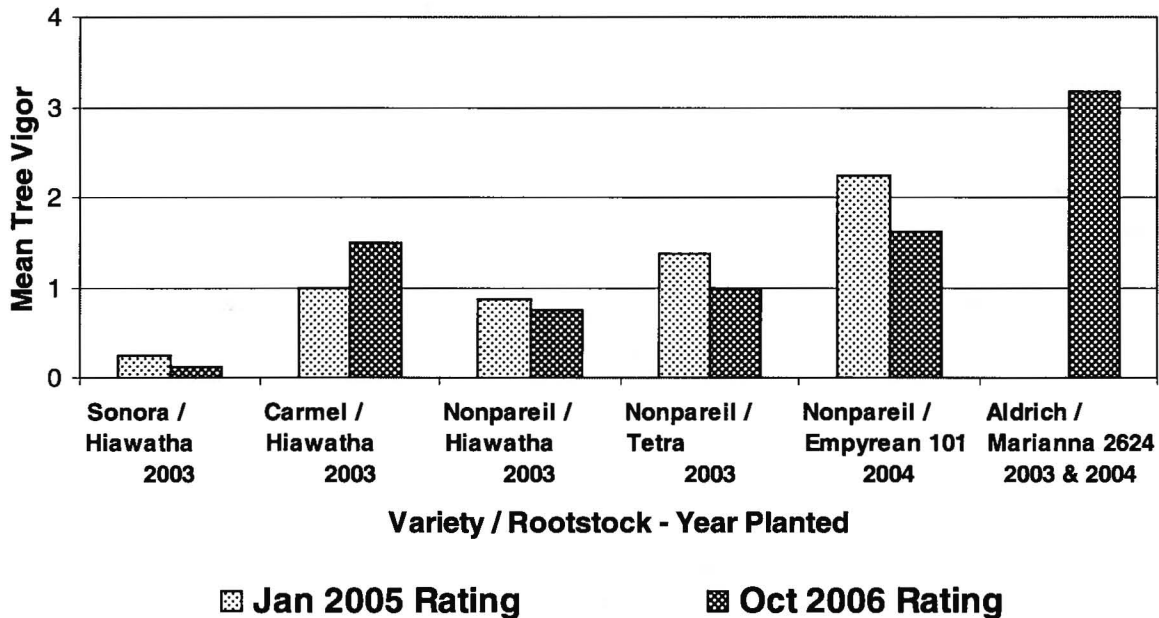


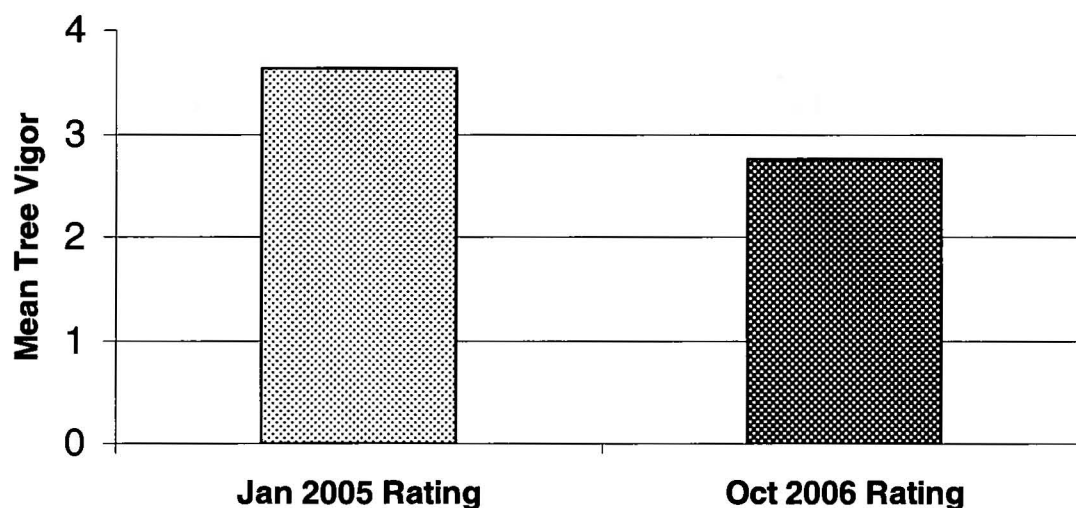
Figure 2. Tree vigor on alternative rootstocks, G&N Creekside Farms, Butte County.



'Nonpareil' trees planted on 'Empyrean 101' have survived so far. They grew well the first year but after three growing seasons this rootstock is producing trees that are small for their age and that have somewhat weaker than normal shoot growth (figs. 2 & 3). They are better than trees on 'Tetra' or 'Hiawatha' but they have weakened in the past two years. In one orchard where comparisons with similar aged 'Aldrich' on Marianna 2624 can be made, the trees on Marianna rootstock are

vigorous and commercially acceptable (fig. 2). Whether almond trees on 'Empyrean 101' will last and be commercially acceptable is still an open question but the current performance of trees on this rootstock is not encouraging.

**Figure 3. Tree vigor of Nonpareil on Empyrean 101 alternative rootstock planted March 2004, Butte County.**



Some of the trees on the 'Ishtara' rootstock have completed their 5<sup>th</sup> growing season and they are the oldest alternative rootstock trees planted in Butte County oak root fungus spots. 'Ishtara' is the most promising of these alternative rootstocks in terms of growth and vigor of the scions. The 'Nonpareil' variety appears to be compatible on 'Ishtara' and its performance has improved in the past two years on this rootstock although the trees are still young. At this point, there has been no sign of *Armillaria mellea* on these young trees. Whether any of these rootstocks will show resistance to this oak root fungus remains to be seen since they are just reaching the age when their roots are extensive enough to be more likely to encounter the disease in old infected roots in the soil profile.

## Alternative Rootstocks For Almonds

**Project Leader:** John Edstrom, UCCE Farm Advisor,  
100 Sunrise Blvd., Suite E  
Colusa, CA 95932  
(530) 458-0570  
jpedstrom@ucdavis.edu

**Project Cooperators:** Stan Cutter, Nickels Trust

### **Interpretive Summary:**

The USDA Agricultural Research Service has identified various plum type rootstocks, which show varying degrees of compatibility with Nonpareil. Two of these, 'Ishtara' and 'Hiawatha' (*Prunus besseyi* x *p. salicina*) have shown some resistance to root knot and root lesion nematodes in field trials. European research has developed a diverse group of *Prunus* rootstocks, some with potential for almonds. Field tests at Nickels Soil Lab now show some of these rootstocks are promising for use with Nonpareil under California conditions.

### **Objectives:**

Evaluate the compatibility and field performance of 'Hiawatha' and other plum rootstock combinations for almond; study the compatibility of newer almond varieties on 'Marianna 2624' plum; and, evaluate promising new European rootstocks.

### **Materials and Methods:**

Tree performance will be evaluated by measuring tree growth, scion/rootstock compatibility and crop yield/quality for the following plantings:

A fifth leaf planting will be evaluated for compatibility of almond varieties on 'Marianna 2624' and 'Hiawatha' plum rootstocks, varieties on M2624 include; 'Plateau', 'Winters'(13-1), and 'Avalon' with 'Sonora' and 'Mission' planted as standards. 'Nonpareil' grafted onto 'Marianna 2624' using a 'Padre' inter-stem is also included along with 'Butte' and 'Nonpareil' on 'Hiawatha'.

A separate planting in small replicated plots will test the performance of Nonpareil on the European rootstocks; 'AC952UC1', 'Pumiselect', 'Penta', 'CM7', 'Jaspi', 'Cadaman', 'Kuban 86', and 'Julior' and on the US selections, 'Ishtara', 'Hiawatha'.

The third block was planted April 20, 2006 using full rows to test Nonpareil on M-40 (sister of M2624) and M2624 both with Padre interstems, and the most promising new rootstocks for the area; 'Hiawatha', 'Ishtara', 'Kuban', and 'Empyrean'.

### **Results and Discussion:**

Average trunk circumference measurements for variety/rootstock combinations are presented in Table 1. Five years growth measurements continue to show that 'Avalon' and 'Winters' are most likely compatible with M2624 rootstock while 'Plateau' is not. 'Numerous 'Plateau' trees show gumming at the graft union and stunted growth (see photo) so typical of compatibility problems when compared to the known compatible variety, 'Mission'. Field experience with 'Sonora' has been reportedly mixed, but in this test, Sonora appears suitable for planting onto M2624. Trees double budded with 'Padre' as an interstem and 'Nonpareil' as a scion, are growing satisfactorily and show promise as a method of producing 'Nonpareil' on M2624 plum rootstock. Tree growth measurements and graft union condition both show that Hiawatha has promise as a

plum root for Nonpareil. However, we have concern over the tendency towards weak anchorage of Hiawatha. Surprisingly, Nonpareil trees on M2624 are still alive.

**Table 1.**

<u>Plum Type Rootstocks</u>	<u>Lbs/acre</u>	<u>Trunk (cm)</u>
Avalon - M2624	762	50.9
Mission - M-2624	968	47.5
Non (F) - M2624	628	44.5
Non - Padre/M2624	839	52.4
Plateau - M2624	577	39.8
Winters (13-1) - M2624	1180	53.8
Sonora - M2624	1165	57.3
Non (F) - Hiawatha	1217	53.1
Butte - Hiawatha	868	52.1
Non (B) - Deep Purple	--	Dead
Non (F) - Deep Purple	--	Dead
Mission - Deep Purple	--	Dead

The small scale test of nine new rootstocks for almonds shows moderate growth characteristics as seen in the Table 2. In this trial, none of the candidates appears vigorous and two, AC 952UC and Pumiselect, and have failed completely.

In the larger scale field test of these new rootstocks only limited observations have been made at this early stage in the evaluation. Subjective visual ratings show the following:

Non/Padre on M2624	very vigorous
Non/Padre on M40	moderately vigorous
Nonpareil on Ishtara	moderately vigorous
Hiawatha	moderately vigorous
Krymsk	vigorous
Empyrean	moderately vigorous

**Table 2.**            **Growth Rating**

Cadaman	3.7
AC 952UC	dead
Hiawatha	3.2
Ishtara	2.8
Jaspi	2.87
Kuban 86 (Krymsk)	3.4
Pumiselect	dead
Penta CM7	3
Julior	4

- 0 = dead
- 1 = extremely stunted
- 2 = poor growth
- 3 = acceptable
- 4 = good growth
- 5 = exceptional growth

Signs of incompatibility, note gumming and overgrowth of scion





