# Field Evaluation of Almond Rootstocks

**Project No.:** **08-HORT4-Duncan**

**Project Leader:** Roger Duncan
Farm Advisor
University of California Cooperative Extension, Stanislaus County
3800 Cornucopia Way, #A
Modesto, CA 95358
(209) 525-6800
raduncan@ucdavis.edu

**Project Coordinators:** Joe Connell, Farm Advisor, University of California Cooperative Extension, Butte County
John Edstrom, Farm Advisor, University of California Cooperative Extension, Colusa County

**Interpretative Summary:**

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.

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

**Primary Investigator:** Roger Duncan, Farm Advisor; University of California Cooperative Extension, Stanislaus County

**Project Coordinators:** Peter & Christene Bacon, grower
Eric Gemperle, grower

### 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.

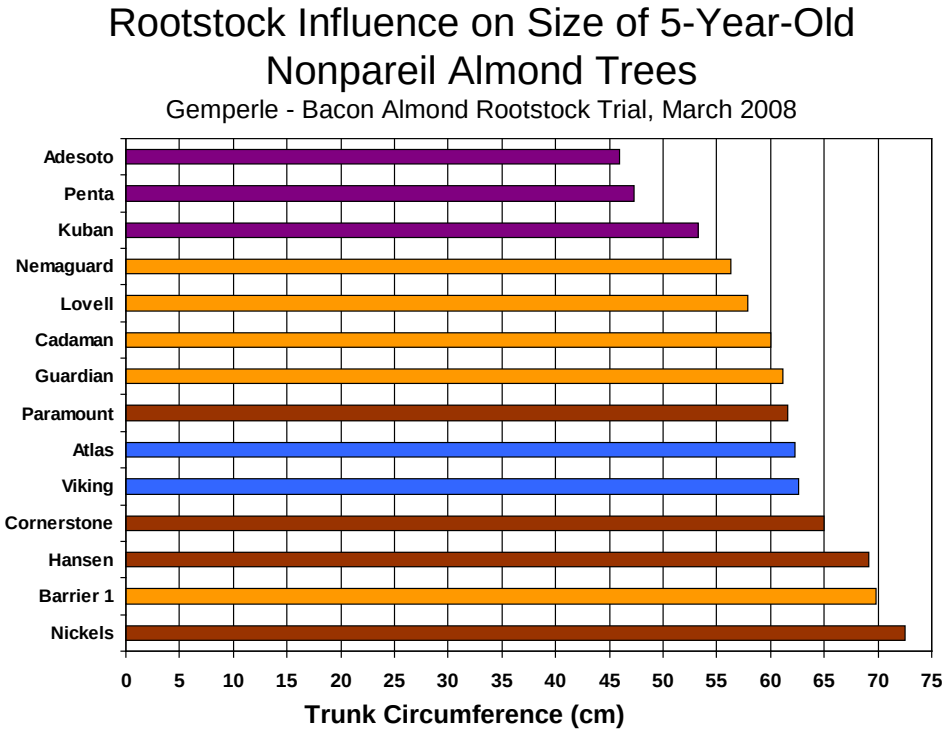
**Table 1**. List of Rootstocks Planted in Almond Replant Trial. Ceres, CA

| 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 |

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$^{th}$-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.



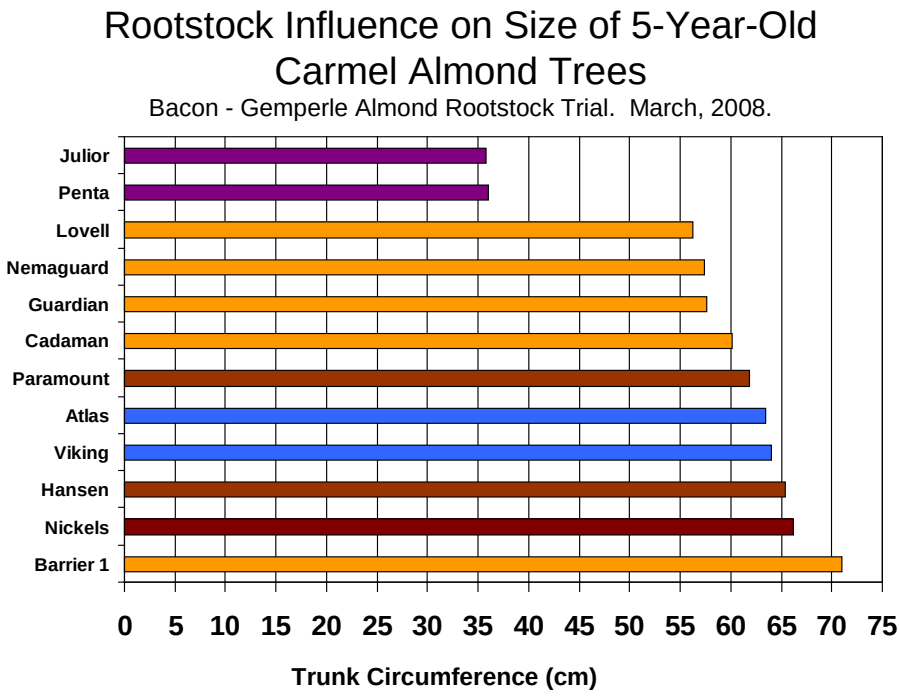



**Table 2.** Yield of Sixth-leaf Almond Trees in a Non-fumigated Replant Site. Bacon / Gemperle Rootstock Trial, 2008. Ceres, CA

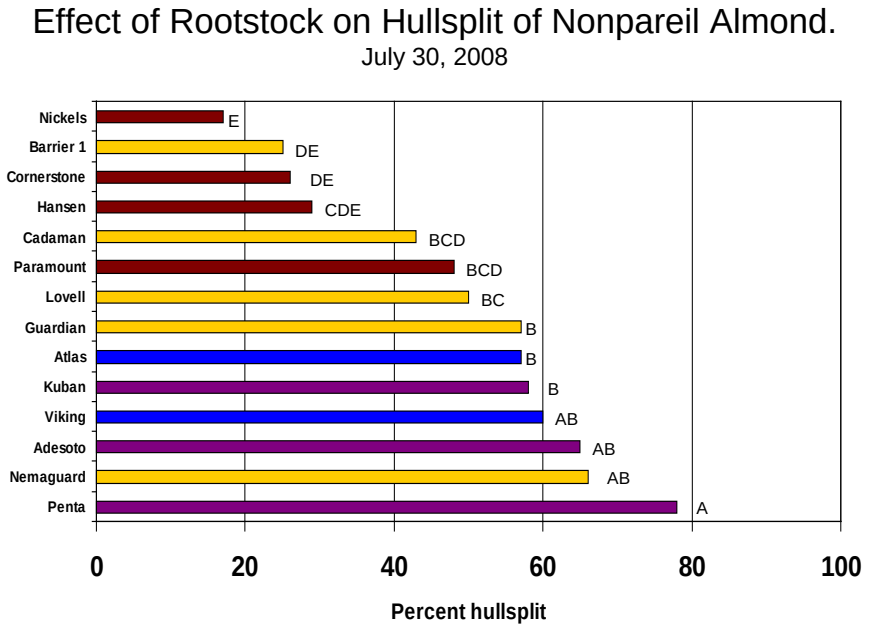
| | Nonpareil | | Carmel | |
|---|---|---|---|---|
| | Yield per Acre* (lb) | Weight per 100 kernels (g) | Yield per Acre* (lb) | Weight per 100 kernels (g) |
| Empyrean #1 | 4381 a | 108.2 ab | 5035** | 121.6** |
| Hansen 536 | 4353 a | 103.8 bc | 4857 ab | 110.0 abc |
| Cornerstone | 4274 a | 105.3 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.




## 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 | |
|---|---|---|---|---|
| | **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 |

## 2) 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:** Joe Connell
Farm Advisor
University of California Cooperative Extension, Butte County

**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:

'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® ('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. 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'.

Some 'Ishtara' rooted trees successfully completed their 7$^{th}$ 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. '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. How long 'Ishtara' will hold up against oak root fungus in these plots remains to be seen.

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'. 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.

### 3) Alternative Rootstocks for Almonds

**Project Cooperator:** John Edstrom
Farm Advisor
University of California Cooperative Extension, Colusa County

**Co-Investigator:** 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. The peach almond hybrid

selections Nickels, Hansens 536 and Brights have filled their space almost completely while the peach rootstocks Nemaguard and Lovell and mixed 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 for 2008, shown in Figure 1 generally show the highest production from the larger P/A 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.

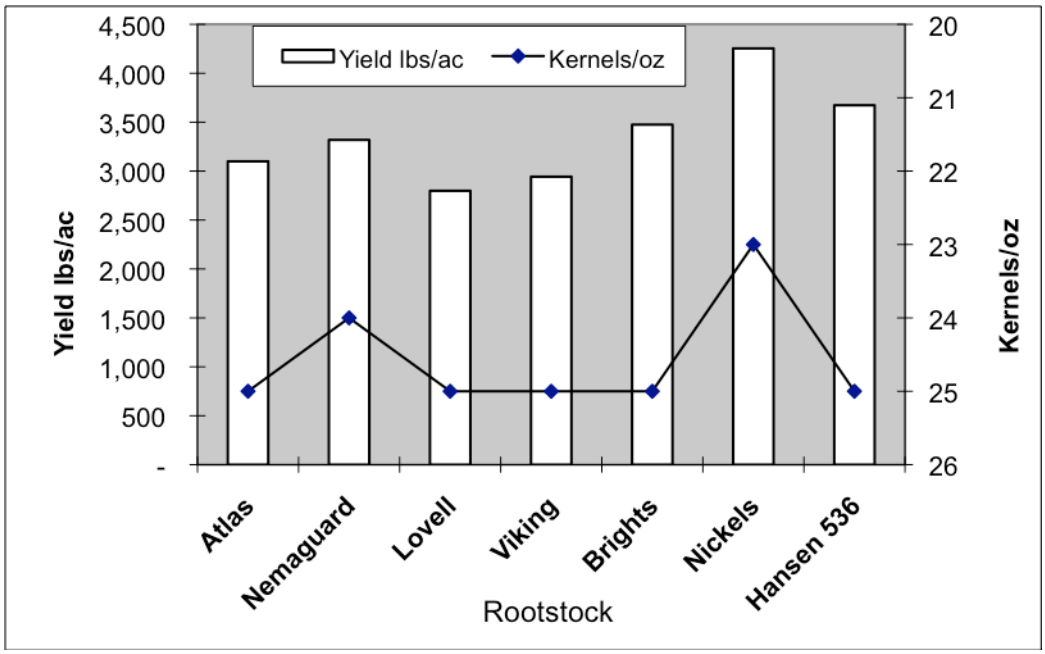
Additionally, all 64 trees of each rootstock were visually rated for gall formations at the soil line from crown gall, *Agrobacterium tumefaciens*. The percentages of trees with galls are given in Table 1. A very high incidence (65%) of crown gall was found in Hansen 536, followed by Nickels (37%), Brights (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 Hansens, 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**.

| Rootstock | Yield lbs/ac | % Crown gall* | Trunk circ. cm |
|---|---|---|---|
| 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.**




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. 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 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 growth 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 (a weakness in peach). Other desirable characteristics identified include very low suckering and tolerance to wet/heavy soils. Preliminary yield figures show Krymsk production 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 again has performed well initially in a test orchard, however poor anchorage has been found in many other locations. The Padre/M-40 interstem alternative has so far performed comparably to the commercial Padre/M-2624 option. Test trees are too young to evaluate the reduced suckering potential reported on this 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**.

| Rootstock | yield lbs/plot | kernels/oz | trunk circ.cm |
|---|---|---|---|
| Ishtara | 420 | 24 | 30.6 |
| Lovell | 418 | 24 | 30.1 |
| Krymsk 86 | 388 | 24 | 29.3 |
| Nickels | 384 | 22 | 31.5 |
| Padre/M2624 | 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.*