# Field Evaluation of Almond Rootstocks

**Project No.:** **11-HORT4-Duncan**

**Project Leader:** Roger Duncan
3800 Cornucopia Way, #A
Modesto, CA 95358
209.525.6800
raduncan@ucdavis.edu

**Project Cooperators and Personnel:**
Joe Connell, UCCE - Butte County
Carolyn DeBuse, UCCE - Yolo & Solano Counties
David Doll, UCCE - Merced County
Brent Holtz, UCCE - San Joaquin County

This is an umbrella project covering several rootstock trials in multiple counties. The field experiments include:

A. **Field Evaluation of Rootstocks for Almond in Non-Fumigated Replanted Orchard Sites.** Joe Connell, UCCE Farm Advisor, Butte County

B. **First Year Performance of 14 Almond Rootstocks in a Sandy Location Irrigated with Well Water.** David Doll, UCCE Farm Advisor, Merced County

C. **Effects of Eight Almond Rootstocks on Nonpareil Tree Growth Grown on Marginal Soil High in Boron.** Carolyn DeBuse, Farm Advisor, UCCE Solano/Yolo Counties

D. **Evaluation of Almond Rootstocks for Westside Soils of the North San Joaquin Valley.** Roger Duncan, UCCE Farm Advisor, Stanislaus County; Brent Holtz, UCCE Farm Advisor, San Joaquin County

E. **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

**Interpretive Summary:**

A. **Field Evaluation of Rootstocks for Almond in Non-fumigated Replanted Orchard Sites** J.H. Connell, UCCE Farm Advisor, Butte County

**Project Cooperators:** Almont Orchards, Brouwer Orchards, M&T Chico Ranch, Sam Lewis & Son Orchards

**Objectives:**

Evaluate variety compatibility with rootstocks for almond, particularly compatibility with Nonpareil. Assess tree field performance and/or tolerance to oak root fungus, high pH clay loam soil, and loam soil in a high rainfall area.

## Materials and Methods:

**Orchard 1)** Replants on alternative rootstocks are planted in non-fumigated oak root fungus spots to gauge their compatibility with almond and survival when exposed to the fungus. 'Nonpareil' on 'Empyrean 101' rootstock has been observed in two orchards since 2004. Nine trees of 'Nonpareil' on 'Krymsk 86' were replanted in oak root fungus spots in spring 2010. A rating scale from 0 to 4 is used to evaluate tree performance with 0 = a very weak tree with almost no growth or poor anchorage and 4 = a very vigorous tree with excellent growth and anchorage.

**Orchard 2)** 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. A quantitative comparison of the effects of variety and rootstock on tree growth is made through trunk circumference measurements of trees on the three rootstocks. Measurements were taken in June 2007 and in fall 2008, 2009, 2010, and 2011. Tree anchorage/mortality is also noted.

**Orchard 3)** Following the removal of a Lovell peach rooted orchard, Greg Browne and I planted a randomized replant disease fumigation trial in 2004 with Almont Orchards in Durham. 20 single tree replicates of 'Krymsk 86', 'Lovell', 'Marianna 2624', and 'Ishtara' rootstocks were planted in both fumigated and non-fumigated tree sites. Although the fumigation trial is complete, observations related to vigor and mortality of the trees on these rootstocks still have value. Trunk circumference measurements were taken to characterize tree size differences and tree anchorage and mortality was noted.

**Orchard 4)** Again, working with Brouwer Orchards in Durham and Fowler Nursery, a new rootstock trial was planted in spring 2010 following the removal of a previous 'Lovell' peach rooted orchard containing some plum rooted replants. This replicated randomized trial will evaluate six rootstocks, all with 'Nonpareil' as the scion, planted with five replicates of ten trees each. The trial is planted on Farwell Loam soil, a relatively heavy series bordering Stockton Clay Adobe. The rootstocks 'Rootpac®', 'Atlas', 'Krymsk 86', and 'Empyrean 1' are compared to standard rootstocks 'Nickels' and 'Lovell'. Tree growth is documented with trunk circumference measurements and mortality and anchorage will be noted as opportunities arise.

## Results and Discussion:

**Orchard 1)** '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 November 2011 in this commercial orchard, four out of seven 'Empyrean 101' rooted trees were leaning. Vigor remains similar to nearby 'Marianna 2624' rooted trees. The orchard was converted to underground drip irrigation in 2010 and appears to have been under-watered in 2011 resulting in relatively little new growth.

Poor anchorage of trees on ‘Empyrean 101’ rootstock precludes the use of this rootstock for almonds. Planted in an oak root fungus spot in 2004, after eight growing seasons, none of these trees have succumbed to *Armillaria mellea*.

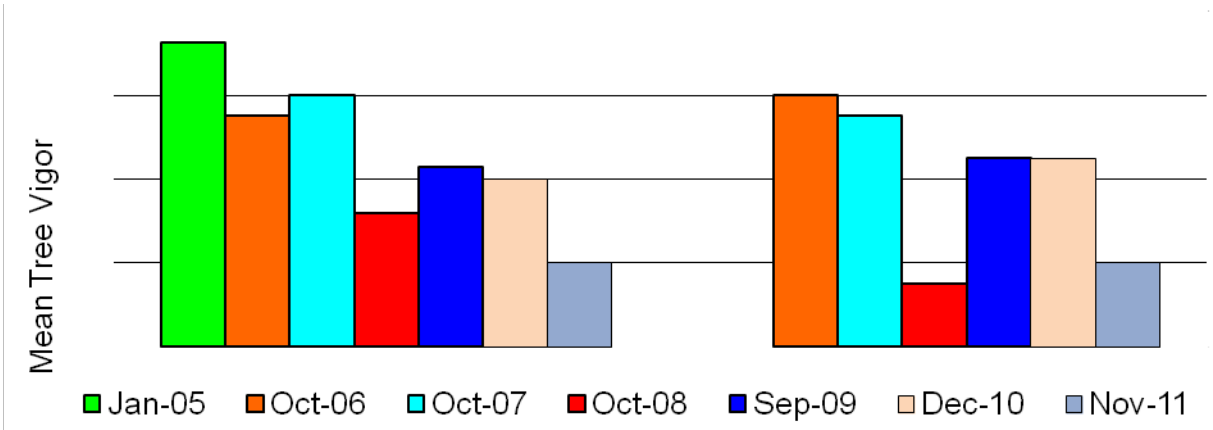


**Figure 1.** Tree vigor of 'Nonpareil' on 'Empyrean 101' rootstock planted March 2004 compared to nearby 'Marianna 2624' replants, Butte County.

All nine ‘Nonpareil’ trees on ‘Krymsk 86’ planted in spring 2010 in three different oak root fungus spots established and grew well the first year. In 2011, all nine trees continue to be healthy. Three of the trees had little growth in 2011 due to installation of a new drip irrigation system where coverage appears to have been inadequate. The other six trees are very vigorous and continue to establish well. Time will tell whether this rootstock is able to resist the fungus and survive. It frequently takes at least 3 or 4 years for a new tree planted on a susceptible rootstock to become infected in an oak root fungus spot.

**Orchard 2)** Planted in 2002 on heavy soil, ‘Ishtara’ is competitive with ‘Lovell’ in terms of tree size, and, trees are more vigorous than trees on ‘Marianna 2624’ (**Table 1**). Although not challenged with oak root fungus in this orchard, ‘Ishtara’ has succumbed to *Armillaria mellea* in other fields. Anchorage can also be a problem for ‘Ishtara’. After six growing seasons, 3 out of 30 trees were lost in high winds in 2008. No additional trees have been lost since then and none of the ‘Lovell’ or ‘Marianna 2624’ rooted trees have been lost.

**Table 1.** Trunk circumference (cm) as influenced by variety and rootstock.

| Scion/Rootstock | 2007 Circ. | 2008 Circ. | 2009 Circ. | 2010 Circ. | 2011 Circ. |
|---|---|---|---|---|---|
| Nonpareil / Lovell | 40.1 | 46.9 | 50.4 | 54.9 | 59.3 |
| Nonpareil / Ishtara | 38.9 | 48.0 | 51.2 | 55.4 | 61.1 |
| Nonpareil / Advantage® | 35.5 | 43.8 | 46.7 | 50.2 | 55.2 |
| Aldrich / Lovell | 42.7 | 48.6 | 54.1 | 58.9 | 64.6 |
| Aldrich / Ishtara | 43.1 | 49.0 | 54.9 | 60.0 | 66.3 |
| Aldrich / Marianna 2624 | 39.3 | 46.9 | 51.7 | 57.7 | 62.2 |
| Butte / Lovell | 47.2 | 53.8 | 58.0 | 63.0 | 66.0 |
| Butte / Ishtara | 42.4 | 51.8 | 56.2 | 60.8 | 65.0 |
| Butte / Marianna 2624 | 39.8 | 48.1 | 52.6 | 55.8 | 59.5 |

**Orchard 3)** In 2004, 'Krymsk 86', 'Lovell', and 'Ishtara' rootstocks were planted in both fumigated and non-fumigated replant tree sites. The observations reported here relate to vigor and mortality of the trees on these rootstocks after eight years.

**Table 2**. 2011 performance on anchorage, disease, and mortality by rootstock.

| | Of Trees Remaining | | Of Original # Trees |
|---|---|---|---|
| Rootstock / Treatment | % Leaning | % with Band Canker | % Missing |
| Ishtara | 47 | 18 | 5 |
| Krymsk 86 | 0 | 24 | 5 |
| Lovell | 8 | 44 | 10 |
| Non-fumigated all rootstocks | 18 | 28 | 0 |
| Chloropicrin all rootstocks | 19 | 29 | 13 |

**Table 2** reports observations on anchorage, disease, and tree mortality by rootstock. These data reinforce information from other trial observations that the 'Ishtara' rootstock is poorly anchored. 'Ishtara' demonstrated the poorest anchorage with 47 percent of the trees leaning. 'Lovell' had 8 percent of trees leaning while none of the trees on the 'Krymsk 86' rootstock were leaning. Both 'Ishtara' and the 'Krymsk 86' rootstocks had 5 percent of the trees missing while 'Lovell' rootstock had 10 percent missing. Interesting but without explanation, all eight trees that were missing from the plot had been pre-plant fumigated with Chloropicrin (13% of the treatment).

Band canker is present in this orchard and the presence of gumming on the trunks was noted. Severity of cankers is not indicated. Some band cankers are minor while others are quite severe possibly threatening tree survival. There is no difference in the percentage of cankering between trees that were pre-plant fumigated and those that were non-fumigated. Over 44 percent of 'Lovell' rooted trees had band cankers on the trunks. Trees on 'Krymsk 86' had 24% of trees with cankers; while 'Ishtara' rooted trees had 18% of the trees showing band cankers.

**Table 3.** Trunk circumference as affected by rootstock and fumigation treatment.

| Rootstock/Treatment | 2009 Average Trunk Circumference (cm) | 2011 Average Trunk Circumference (cm) |
|---|---|---|
| Ishtara/Check | 35.2 | 42.0 |
| Ishtara/Chloropicrin | 36.7 | 43.1 |
| Krymsk 86/Check | 40.8 | 48.7 |
| Krymsk 86/Chloropicrin | 41.2 | 49.0 |
| Lovell/Check | 34.2 | 40.4 |
| Lovell/Chloropicrin | 37.8 | 44.2 |

Trunk circumference measurements indicate tree size differences and are a reflection of tree vigor. All three rootstocks benefited from Chloropicrin fumigation but the greatest improvement

in tree vigor was noted in trees on the 'Lovell' peach rootstock (**Table 3**). Trees on the 'Krymsk 86' rootstock have the largest trunk circumference, roughly 6 centimeters larger than the other two rootstocks. When trunk circumference measurements by rootstock for both fumigated and non-fumigated treatments are averaged, the circumference of the 'Ishtara' and 'Lovell' rooted trees are nearly identical.

**Orchard 4)** These six rootstocks were planted on March 15, 2010. 'Rootpac®', 'Atlas', 'Krymsk 86', and 'Empyrean 1' are all compared to standard rootstocks 'Nickels' and 'Lovell', all with 'Nonpareil' scions. Four of the six rootstocks established well in the first growing season with no tree losses. 'Atlas' suffered 10% mortality at planting and 'Nickels' lost 16% of the new trees (**Table 4**). Both of these rootstocks had poor root development on the bare root trees and root volume was limited compared to other rootstocks. The normal practice in this field is to double stake each tree. We noted the number of trees on the various rootstocks that were triple staked by the cooperator as a possible indicator of young tree anchorage. A true test of anchorage has not yet occurred in this orchard. After the first and second growing seasons, trees on the 'Empyrean 1' rootstock were the largest in circumference and those growing on 'Krymsk 86' were the smallest.

**Table 4.** Trunk circumference and tree loss at planting.

| | Trunk Circumference (cm) | | % Trees | % Loss |
|---|---|---|---|---|
| Rootstock | Fall 2010 | Fall 2011 | Triple Staked | At Planting |
| Lovell | 9.6 | 21.5 | 2 | 0 |
| Atlas | 9.6 | 21.7 | 9 | 10 |
| Empyrean 1 | 10.5 | 23.9 | 0 | 0 |
| Rootpac-R | 10.2 | 22.6 | 4 | 0 |
| Krymsk 86 | 8.8 | 20.5 | 8 | 0 |
| Nickels | 10.1 | 22.6 | 21 | 16 |

## B. First Year Performance of 14 Almond Rootstocks in a Sandy Location Irrigated with Well Water.

David Doll, Farm Advisor, Merced County

**Project Cooperators:** Glen Arnold, Arnold Farms; Larry Burrows, and Andrew Ray

**Objective**:

To compare rootstock performance based upon growth, nematode counts, tissue sampling, and yield within the test location that experiences the following conditions: low exchange capacity soil, presence of ring, rootknot, and lesion nematode, high sodium and nitrate within water used for irrigation, and areas of hardpan and shallow soil. Efforts will also be made to observe various phenological differences of these rootstocks such as bloom and harvest timing and influence on various diseases.

## Background:

This replicated trial was established in January of 2011 in Winton, CA in Atwater Sand. It is comparing the performance of Nonpareil on 14 rootstocks, and the performance of Fritz and Monterey on seven rootstocks (**Table 1**). Each rootstock and variety combination will have 6 trees within a block, with six replicate blocks. Many of the rootstocks are peach/almond hybrids (P/A-Hybrids) as the grower has developed an interest in these rootstocks since the participation in a previous UC rootstock trial. Prior to planting, the location was cover cropped with Merced Rye, tree sites were excavated, and the row-strips were fumigated with Telone-II at 33 gallons per acre. Trees were planted in January, 2011 with the exception of the trees grafted to Cadamen and Cornerstone; both were planted in April, 2011. Spacing is 22'x18' and trees are irrigated using double line drip.

## Methods:

Soil mapping was done using Veris Electrical Conductivity Mapping (Strategic Farming). Zones of soil differences were identified (**Figure 1**), analyzed (**Table 2**), and used to help establish experimental blocks. Shortly after planting, initial trunk diameter measurements were taken. Follow up measurements were taken after the first season of growth. Light interception was carried out on 3 trees within blocks 1 -3 by measuring the amount of shade casted onto tarps placed on the ground at mid-day during July. Stem water potential (SWP) was collected from 3 trees of each rootstock within blocks 1-3 using standard procedure. Each block was measured four times throughout the season, for a total of 12 36 SWP measurements for each rootstock. Water samples were collected twice within the growing season to determine water quality. Nematode samples were collected in October, 2011. Observations of bloom percentage as influenced by variety and rootstock were taken on February 22$^{nd}$, 2012.

## Results and Discussion:

Soil quality was suitable for almond production (**Table 2**), although considerable soil differences were found amongst blocks (**Figure 1**). Water analysis found high levels of nitrate-nitrogen, and moderate levels of sodium (**Table 3**). Vigorous growth was observed across all blocks and rootstocks; this may be due to the amount of nitrogen available from the groundwater.

Tree growth was similar across all three varieties. Within 'Nonpareil,' 'Red Titan III,' 'Cadaman,' and 'Cornerstone' did not perform as well as the other 11 rootstocks (**Table 4**). 'Red Titan III' experienced poor root growth due to a production problem which has been confirmed by the nursery. 'Cadaman' and 'Cornerstone' were planted four months later than the other 12 rootstocks. There were no differences determined between rootstocks for the varieties 'Fritz,' and 'Monterey' (**Table 5**).

Light interception differed amongst rootstocks. 'Atlas,' 'BB106,' 'BH5,' Empyrean-1,' 'FloridaguardxAlnem,' 'Hansen,' 'Nemaguard,' and 'Viking' had the highest mid-day light interception (**Table 4**). These rootstocks grew very large, vigorous trees as indicated in the change in caliper growth. The poor performance observed with 'Cornerstone,' and 'Cadamen' grafted trees was most likely due to the later planting date.

Rootstock did influence progression of bloom (**Table 6**). All trees grafted to 'Nonpareil' performed similarly, except 'Cadamen,' Krymsk-86,' and 'Cornerstone' which had the lowest percentage of bloom observed. Within the varieties 'Fritz' and 'Monterey,' the rootstocks 'Atlas,' 'Empyrean-1,' 'Hansen,' and 'Viking' had the highest bloom percentage. The 'Fritz' and 'Monterey' trees on these rootstocks are larger and appear to be more vigorous which may possibly explain the advanced bloom progression.

All first leaf trees had similar stem water potential (SWP), but differences were found. Krymsk-86 and RootpacR had the lowest SWP (most stressed) over the course of the season (**Table 7**). Both of these rootstocks have plum parentage, which may need different irrigation management in comparison to the other rootstocks.

Nematode samples were collected from all of the rootstocks in five of the six blocks (blocks 2-6). There were no detectable populations of nematodes found in any of the rootstocks (data not shown). Nematode populations usually take 2-3 years to move into fumigated soil and sampling for ring, rootknot, and lesion nematodes will be continued over the next few years.

**Table 1.** Almond rootstocks selected for January, 2011 planting at a location with sandy soil and low quality irrigation water. Seven rootstocks were planted on 'Nonpareil', 'Fritz', and 'Monterey'; seven were planted on 'Nonpareil' only.

| **Rootstocks planted on Nonpareil, Fritz, and** | **Rootstocks planted on Nonpareil, Only** |
|---|---|
| Nemaguard | RootPac (R) |
| Hansen 536 | TemprPac |
| BH5 | Krymsk-86 |
| Viking | Cornerstone* |
| Atlas | Cadaman* |
| Empyrean-1 | BB#106 |
| Red Titan III | Floridaguard x Alnem (USDA) |

*Indicates rootstocks were planted in May, 2011 due to nursery availability.

**Table 2.** Soil analysis of the six blocks established within the rootstock trial. Samples were collected in October, 2010 and sent to UC Davis's Analytical Laboratory for analysis.

| | Soil Classification | Organic % | P - PPM | K PPM | Mg PPM | Ca PPM | Na PPM | pH | CEC meq/100 | Base Saturation % K | Mg | Ca | H | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Block | Sandy Loam | 0.7 | 16 | 68 | 264 | 1172 | 85 | 7.0 | 8.6 | 2.0 | 25.4 | 68.3 | 0 | 4.3 |
| Block | Sandy Loam | 0.5 | 36 | 63 | 141 | 668 | 39 | 6.6 | 5.1 | 3.1 | 22.6 | 64.9 | 6.0 | 3.3 |
| Block | Loamy Sand | 0.4 | 55 | 56 | 73 | 366 | 16 | 6.7 | 2.8 | 5.2 | 21.8 | 66 | 4.5 | 2.6 |
| Block | Loamy Sand | 0.4 | 72 | 52 | 62 | 290 | 25 | 6.0 | 2.6 | 5.2 | 19.7 | 55.9 | 15 | 4.2 |
| Block | Loamy Sand | 0.5 | 33 | 58 | 81 | 377 | 25 | 6.5 | 3.0 | 4.9 | 62.1 | 62.1 | 7.5 | 3.6 |
| Block | Loamy Sand | 0.7 | 82 | 64 | 207 | 845 | 82 | 6.6 | 6.8 | 2.4 | 24.8 | 61.5 | 6.0 | 5.2 |

**Table 3**. Analysis of well water from the trial location. Samples were collected in July (Mid Season) and October (Late Season), 2011 and sent to UC Davis's Analytical Laboratory for analysis.

| | pH | EC | SAR | Ca | Mg | Na | Cl | B | HCO3 | CO3 | NO3- |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mid Season | 7.89 | 0.52 | 0.9 | 2.50 | 1.50 | 1.23 | 0.42 | 0.03 | 2.1 | <0.1 | 19.6 |
| Late Season | 7.90 | 0.52 | 0.8 | 2.44 | 1.47 | 1.18 | 0.42 | 0.03 | 2.1 | <0.1 | 17.2 |

**Table 4.** Seasonal change in trunk diameter (mm) and mid-day light interception ($m^2$) of 'Nonpareil' almond scion grafted to 14 different rootstocks. Trees were planted in January, 2011. Means without letters in common are significantly different, *P*=0.05.

| | Change in Trunk Diameter (mm) | Mid-Day Light Interception ($m^2$) |
|---|---|---|
| Atlas | 45.83 AB | 2.38 AB |
| BB106 | 47.27 A | 3.30 A |
| BH5 | 43.73 AB | 2.49 AB |
| Cadaman* | 25.47 C | 0.73 CD |
| Cornerstone* | 26.52 C | 1.11 CD |
| Empyrean-1 | 46.50 AB | 2.88 AB |
| FloridaguardxAlnem | 43.20 AB | 2.91 AB |
| Hanson | 45.90 AB | 2.62 AB |
| Krymsk-86 | 41.68 AB | 1.92 BCD |
| Nemaguard | 42.88 AB | 2.20 ABC |
| Red Titan III | 39.25 B | 1.66 BCD |
| RootPacR | 42.82 AB | 2.00 BC |
| TemproPac | 44.80 AB | 2.03 BC |
| Viking | 46.94 AB | 2.20 ABC |

* indicates a potted tree planted in mid-April.

**Table 5.** Seasonal change in trunk diameter (mm) of almond varieties 'Fritz' and 'Monterey' on seven different rootstocks planted in January 2011.

| | Fritz | Monterey |
|---|---|---|
| Atlas | 45.5 | 47 |
| BH5 | 39.5 | 43.2 |
| Empyrean- | 43.7 | 49.6 |
| Hanson | 44.2 | 47.7 |
| Nemaguard | 44 | 44.2 |
| Red Titan | 41.6 | 42.7 |
| Viking | 46.4 | 48.8 |

**Table 6.** Bloom percentage of the variety 'Nonpareil' on 14 rootstocks and varieties 'Fritz,' and 'Monterey' on seven rootstocks. Observations were taken on February 22nd, 2012. Means without letters in common are significantly different, *P*=0.05.

| | Nonpareil | Fritz | Monterey |
|---|---|---|---|
| Atlas | 52.5 AB | 30.8 | 44.2 AB |
| BH5 | 43.3 AB | 11.7 C | 25.8 AB |
| Empyrean-1 | 75.8 A | 68.3 A | 70.8 A |
| Hanson | 64.2 AB | 51.7 | 66.7 AB |
| Nemaguard | 54.2 AB | 26.7 | 23.3 B |
| Red Titan III | 28.2 AB | 25.8 | 32.5 |
| Viking | 74.2 A | 35.5 | 53.3 |
| BB106 | 62.5 AB | | |
| Cadaman | 20.8 BC | | |
| Cornerstone | 10.8 C | | |
| Floridaguard x | 34.2 AB | | |
| Krymsk-86 | 16.7 BC | | |
| RootPacR | 29.2 AB | | |
| TemprPacR | 36.7 AB | | |

**Table 7**. Stem water potential measurements sampled from 14 rootstocks grafted to 'Nonpareil' for the 2011 growing season. Number reported is difference from baseline determined from temperature and humidity of the day measurements were taken. Means without letters in common are significantly different, *P*=0.05.

| Rootstock Nonpareil Scion | SWP off (bars) | Mean Grouping (p<0.05) |
|---|---|---|
| Atlas | -1.49 | AB |
| BB106 | -1.86 | AB |
| BH5 | -1.94 | AB |
| Cadaman | -2.2 | AB |
| Cornerstone | -2.07 | AB |
| Empyrean-1 | -2.06 | AB |
| Flor x Alnem | -1.17 | A |
| Hansen | -1.57 | AB |
| Krymsk-86 | -2.54 | B |
| Nemaguard | -1.62 | AB |
| Red Titan | -2.19 | AB |
| RootPacR | -2.54 | B |
| TemproPac | -2.04 | AB |
| Viking | -1.52 | AB |

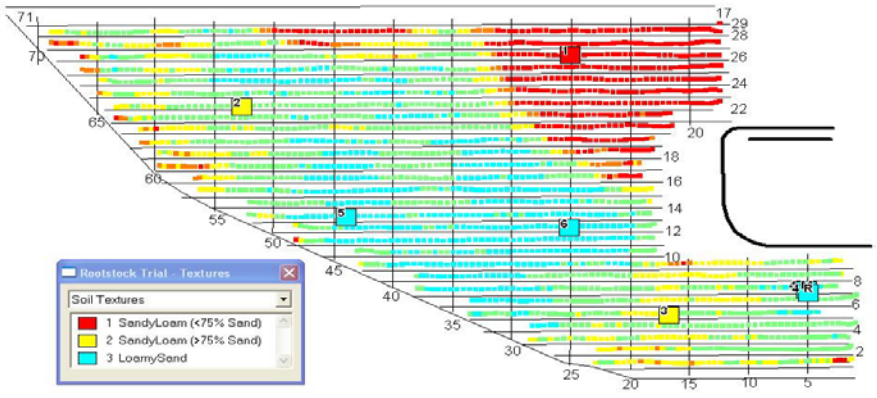


**Figure 1.** Soil electrical conductivity (EC) map of the rootstock plot. Red areas indicate heavier soil, while blue indicates lighter, coarser soil. EC mapping provides the ability to distinguish soil variations that are not detectable from viewing soil surveys. Differences in EC indicate different water and nutrient holding capacities.

## C. Effects of Eight Almond Rootstocks on Nonpareil Tree Growth Grown on Marginal Soil High in Boron

Carolyn DeBuse, Farm Advisor, UCCE Solano/Yolo Counties

### Objectives:

The objective of this study is to evaluate plant growth and boron uptake of Nonpareil almond on eight different rootstocks in the Sacramento Valley when grown on marginal soil high in boron.

### Interpretive Summary:

As the almond industry expands in the Sacramento Valley, growers are increasingly planting new orchards on marginal soil using lower quality water sources. Almonds are generally more tolerant of drought and shallow soils than other tree crops, but in the Sacramento Valley the marginal soils are often wetter, heavier clay. These heavier soils can be problematic with water logging and restrictive clay layers inhibiting root growth. To make matters worse, in Yolo County the soils and water are additionally high in boron. These soil limitations are not unique to Yolo County. Heavy soils are found throughout the northern Sacramento Valley. While in the southern west side of the San Joaquin Valley boron levels are so high in some areas that they prohibit agriculture. The plot chosen for this trial will test both of these soil limitations in the evaluation of eight almond rootstocks.

Previous research and observational data showed seven rootstocks that may tolerate boron better than the commonly grown Lovell peach. They are Hansen, Nickels, Floraguard x alnem hybrid (FXA), Krymsk 86, Brights-5, Rootpac-R, and Viking. This trial is an opportunity to test if there are differences in boron uptake between rootstocks and evaluate these rootstocks' performance on heavier, marginal soils. An additional rootstock was added after the initial

planting, Titan SG1, data collected from this rootstock will be included in the report but considered observational.

The trial is located in Yolo County north of Cache Creek. Nonpareil almond nursery grafted trees on eight different rootstocks (Lovell, Hansen, Nickels, Floraguard x alnem hybrid (FXA), Krymsk 86, Brights-5, Rootpac-R, and Viking) were planted on February 9, 2011. All trees were bareroot except Brights-5 which was potted. The soil is classified as Marvin silty clay loam with a Storie Index (CA) of 65. Twenty trees of Titan SG1 (potted) were planted on April 22, 2011 within the same orchard but not in the replicated trial. The trial is a randomized complete block design with 6 replicates of each rootstock, 5 trees per replicate. This totals to 30 trees per rootstock with a total of 240 trees in the trial. Tree diameter and height were measured in late fall. In the crop bearing years, data on bloom time, nut maturity, nut removal and nut quality will be collected. Soil samples were collected at 12 and 24 inch depths randomly and bulked by block and analyzed for chemical composition and nematodes.

There were no tree losses the first year of the trial and all trees grew well. The average measurements are shown in the **Table 1**. There were significant differences between rootstocks for both the diameter and the height. Lovell had a significantly larger average trunk diameter while FxA was significantly taller than the rest. Brights-5 was smallest in diameter and shortest but this was likely due to being potted instead of a bareroot. The small size of Titan SG1 was likely due to the fact it was also potted and planted much later. The difference seen in 2011 relate more to the size at planting and type of nursery tree (bareroot or potted) than the rootstock itself. These differences may equal out after one or two years of growth.

Soil analysis: The soil sample averages are as follows; pH 7.47, Ca 0.84 meq/L, Mg 1.18 meq/L, Na 2.00 meq/L, Cl 0.03 meq/L. The Boron averaged at 12 inches 1.42 mg/L and 1.91 mg/L at 24 inches. The soil particle size averaged 11% sand, 48% silt, 41% clay.

Water boron levels: surface water from Cache Creek fluctuate between 1.0-2.0 ppm as reported by Yolo County Flood Control & Water Conservation District.

**Table 1**. Average trunk diameter and tree height measurements (±standard deviation) of Nonpareil almond grown on nine rootstocks. Letters indicate the significant differences between treatment means at the level p≤ 0.05 using Duncan's multiple range test.

| | Mean Trunk Diameter (mm), 18' above soil, April 2011 (± SE) | Mean Trunk Diameter (mm), 18' above soil, October 2011 (± SE) | Mean Tree Height (cm) October 2011 (± SE) |
|---|---|---|---|
| **Lovell** | 14.58 (0.25) | 42.06 (0.64) a | 223 (1.79) ab |
| **Hansen 536** | 9.10 (0.25) | 38.15 (0.40) c | 214 (1.97) c |
| **Nickels** | 14.09 (0.21) | 40.50 (0.52) b | 219 (2.23) bc |
| **FXA** | 13.63 (0.25) | 39.51 (0.47) b | 228 (2.32) a |
| **Krymsk 86** | 13.95 (0.18) | 37.82 (0.39) c | 223 (1.67) ab |
| **Brights-5** | 8.36 (0.19) | 35.59 (0.32) d | 201 (1.60) d |
| **Rootpac-R** | 13.87 (0.31) | 39.74 (0.36) b | 216 (2.11) c |
| **Viking** | 15.26 (0.28) | 39.75 (0.51) b | 214 (1.24) c |
| **Titatn SG1** | na | 29.77 (0.46) | 198 (2.47) |

## D. Evaluation of Almond Rootstocks for Westside Soils of the North San Joaquin Valley.

Roger Duncan, UCCE Farm Advisor, Stanislaus County
Brent Holtz, UCCE Farm Advisor, San Joaquin County

### Objectives:

Document the performance of alternative almond rootstocks grown on the Westside of the North San Joaquin Valley, where the soils are relatively heavy and alkaline and the pH and dissolved salts in the irrigation water are often higher than optimal for the rootstock standard nemaguard.

### Interpretive Summary:

The Westside of the North San Joaquin Valley has traditionally been planted to row crops with relatively few acres of fruit and nut trees. More and more almond orchards are being planted in this area now and the majority is being planted on Nemaguard. Nemaguard is not well suited for heavy, alkaline soils with marginal irrigation water. Yields in westside orchards are chronically lower than eastside orchards, likely, at least in part, to the use of inappropriate rootstocks. We know that peach / almond hybrid rootstocks like Hansen are better suited to alkaline soils, but there is concern about their increased susceptibility to root diseases which are often more prevalent in these heavy soils. This trial will compare the performance of Nemaguard to fifteen alternative rootstocks growing under "typical" westside growing conditions.

## Materials and Methods:

This trial was planted on December 21, 2011 near Highway 33 south of the town of Westley in a western Stanislaus County commercial almond orchard. The soil is classified as a Zacharias clay loam. Preliminary soil analysis indicated that the soil is high in boron (1.7 ppm) and magnesium (555 ppm) with moderately high pH (7.5) and soluble salts (1.3 mmhos / cm). The orchard will be irrigated with a combination of well water and San Joaquin River water which is often high in dissolved salts, especially during the later part of the season. No appreciable populations of pathogenic nematodes were detected prior to planting. The field has a long history of melons and tomatoes which often harbor the Verticillium wilt fungus.

The trial, with Nonpareil as the scion, consists of sixteen rootstocks, including hybrids of various peach species, peach x almond, peach x plum, almond x plum, peach x almond x apricot x plum and complex peach x almond crosses. Each rootstock is replicated six times in a randomized complete block design with five trees per replication. Most trees were planted bareroot with the exception of Avimag, HBOK 50, and Brights #5 which were potted trees. The spacing in the orchard is 16' x 20' (136.1 trees per acre). The list of rootstocks is shown below:

| | | |
|---|---|---|
| 1. | Nemaguard | *P. persica* |
| 2. | Lovell | *P. persica* |
| 3. | Empyrean 1 | *P. persica x P. davidiana* |
| 4. | Avimag | *P. persica x P. davidiana* |
| 5. | HBOK 50 | Harrow blood x Okinawa peach |
| 6. | Hansen | *P. dulcis x P. persica* |
| 7. | Brights #5 | *P. dulcis x P. persica* |
| 8. | BB 106 | *P. dulcis x P. persica* |
| 9. | Paramount | *P. dulcis x P. persica* |
| 10. | Flordaguard x Alnem | *P. persica* x Israeli bitter almond |
| 11. | PAC9908-02 | (*P. dulcis x P. persica*) x *P. persica* |
| 12. | HM2 + | Hansen (P*. dulcis x P. persica*) x Monegro (*P. dulcis* x *P. persica*) |
| 13. | Viking | *P. persica* (Nemaguard) x (*P. dulcis*) x [*P. cerasifera x P. armeniaca*) |
| 14. | Atlas | *P. persica* (Nemaguard) x (*P. dulcis*) x [*P. cerasifera x P. armeniaca*) |
| 15. | Krymsk 86 | *P. cerasifera x P. persica* |
| 16. | Rootpac R | almond x plum |

## Results and Discussion:

Halfway through the first growing season, all trees appear to be establishing well. Only one tree (a Viking) out of all 480 test trees failed to grow initially and had to be replaced. Tree size (trunk circumference and tree height) will be measured at the end of the first growing season. In the crop bearing years, data on bloom time, hull split, nut quality and yield will be collected. After trees become established for three or four years, leaf analyses will be conducted to determine differences in nutrient content among the rootstocks and to monitor the accumulation of boron, sodium and chloride. Soil and water samples will be analyzed periodically to document changes through the years. Any differences in disease or other parameters of performance will be noted if they occur.

**E. 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 *Prunus* spp. rootstocks which are 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 and perform adequately in sandy soil. 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. The trial, which includes the rootstocks Empyrean 2 (a.k.a. Penta), Tetra, Hiawatha, Ishtara, Krymsk 86, Marianna 26-24, Marianna 40, Nemaguard and Viking was planted in January 2007. The scion varieties are Butte and Padre. Tree spacing is 16' x 21'.

**Results:**

In 2011 (5$^{th}$ leaf), yield was determined by hand raking field dried nuts from under the trees and weighing them on a field scale. Subsamples were counted and hand cracked to document kernel quality and yield. In general, Nemaguard, Viking and Krymsk 86 had the highest yields while Tetra, Marianna 26-24, Hiawatha and Empyrean 2 had the lowest yields. Marianna 40 yielded significantly more than Marianna 26-24 and had no root or crown suckers. Calculated yield was positively correlated with tree size (larger trees had higher calculated yields).

| **Yield and Sucker Severity** | | | |
|---|---|---|---|
| | Calculated Yield (kernel lb / acre) | | Suckers / tree |
| | Butte | Padre | |
| Nemaguard | 3294 a | 2658 ab | 0 |
| Viking | 2581 ab | 3023 a | 0 |
| Krymsk 86 | 2769 ab | 2610 ab | 0.1 |
| Marianna 40 | 2245 b | 2380 ab | 0 |
| Ishtara | 2155 b | 1909 bc | 0 |
| Empyrean 2 | 1640 bc | 2117 b | 1.1 |
| Hiawatha | 1553 c | 1861 bc | 0.3 |
| Marianna 26-24 | 1580 c | 1646 c | 5.8 |
| Tetra | 1733 bc | 1334 c | 0.4 |

**Tree size.** Most rootstocks have grown adequately into their sixth leaf. Trees on Viking and Nemaguard are the largest while trees on Tetra, and Empyrean 2 are the smallest. Butte trees on Hiawatha are also very small but Padre trees on Hiawatha are more moderate in size. Trees on Krymsk 86, a promising new peach x plum hybrid, are growing well and are only a little smaller than trees on nemaguard (although not statistically different). Trees on Marianna

40 tend to be 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 4$^{th}$ leaf), two Butte trees on Marianna 26-24 showed signs of union mild etch. These signs of partial incompatibility had faded by mid-summer and no signs have been evident since. No signs of oak root rot have appeared yet in this trial.