Field Evaluation of Almond Rootstocks

Project No.: **13-HORT4-Duncan**

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Objectives:

A. Evaluate alternative rootstocks irrigated with low quality (saline) irrigation water in low pH, sandy soil (Merced County) and in high pH, loamy clay soil (west side, Stanislaus County).

B. Evaluate alternative rootstocks under high boron conditions (Yolo County).

C. Continue evaluation of alternative rootstocks for tolerance to Armillaria root and crown rot (Butte & Stanislaus Counties).

D. Continue evaluation of variety compatibility with rootstocks for almond, particularly compatibility with Nonpareil.

E. Continue evaluation of alternative rootstocks in a sandy, unfumigated replant location (Stanislaus County).

Interpretive Summary:

A. In general, across all trials, trees on peach x almond rootstocks (or hybrids of peach x almond hybrids), including Hansen, Nickels, Cornerstone, BB 106, Flordaguard x Alnem, PAC9908-02, Tempropac and HM2 are the largest and tend to have the highest yields.

B. Empyrean 1, a peach x peach hybrid rootstock, is often as large as the peach x almond hybrid rootstocks with similar yields.

C. Atlas has high yields for its moderate tree size.

D. In a Butte County trial, 47% of the trees on Ishtara and 8% of Lovell trees are leaning while none of the trees on Krymsk 86 are leaning after ten years.

E. In a Merced County trial in sandy soil, trees on Krymsk 86 and RootPac R showed significantly greater water stress than Atlas, Floridaguard x Alnem, and Hansen 536 based on pressure chamber measurements.

F. In the same trial, trees on Empyrean 1, Viking and Hansen rootstocks tended to bloom a little earlier than Nemaguard.

G. In a West Stanislaus trial following decades of row crops, Nonpareil trees on Lovell had the highest incidence of Verticillium while Hansen had the most severe symptoms in the third leaf. Atlas and HM2 appear to be highly tolerant of Verticillium and have shown no signs of the disease after three years.

H. In an East Stanislaus trial, Nemaguard, Lovell, Guardian, Atlas and Krymsk 86 had very high leaf levels of sodium and chloride and exhibited severe signs of salt toxicity by late summer. Sodium levels were low in Cornerstone, Paramount, Adesoto, Hansen and Empyrean 1 and they showed no signs of salt burn.

I. In a Yolo County trial with very high boron in the soil, hull boron was very high in all rootstocks but tended to be highest in Lovell (673 ppm) and lowest in Viking (511 ppm) and Nickels (519 ppm).

Field Evaluation of Rootstocks for Almond in Non-fumigated Replanted Orchard Sites

Project leader: J.H. Connell, UCCE Advisor Emeritus, Butte County

Objective:

Evaluate Nonpareil compatibility with rootstocks for almond. Assess tree field performance and/or tolerance to oak root fungus.

Materials and Methods:

A) Replants on alternative rootstocks are planted in non-fumigated oak root fungus spots to gauge their survival when exposed to the fungus. Nonpareil on Empyrean 101 rootstock has been observed in two orchards since 2004. Nine Nonpareil trees on Krymsk 86 were replanted in oak root fungus spots in Spring 2010 and ten trees on another experimental rootstock were planted in 2012.

B) 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. Twenty 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 are taken periodically to characterize tree size differences and tree anchorage and mortality will be noted.

C) Working with Brouwer Orchards in Durham and Fowler Nursery, a new rootstock trial was planted in March 2010 following the removal of a previous Lovell peach rooted orchard containing some plum rooted replants. This replicated randomized trial has six rootstocks, all with Nonpareil as the scion, planted with five replicates of ten trees each. Trees were 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 will be documented with trunk circumference measurements, mortality and anchorage will be noted, and yield data will be collected.

Results (to date):

A) All nine Nonpareil trees on Krymsk 86 planted in Spring 2010 in three different oak root fungus spots continue to be healthy through the 4th growing season while a Lovell rooted replant of similar age in one of the fungus spots died. Ten Nonpareil trees planted in 2012 on another new rootstock being screened for potential *Armillaria* resistance established well and have so far remained healthy. Nonpareil trees on Empyrean 101 are prone to leaning but are similar in size and vigor to nearby trees on Marianna 2624.

B) There were no observations made on this old fumigation/rootstock trial during the 2013 season. Prior observations show Krymsk 86 trunk circumference was largest while Lovell benefited most from fumigation. After 8 years, 47% of Ishtara trees and 8% of Lovell trees were leaning. There were no leaning trees on Krymsk 86 rootstock.

C) In this trial consisting of six rootstocks, 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 (data presented in 2012 annual report, 12-HORT4-Duncan). After the third growing season, trees on the Empyrean 1 rootstock were largest in circumference and those growing on Krymsk 86 were the smallest. Trees on the other rootstocks were intermediate in circumference (**Figure 1**).

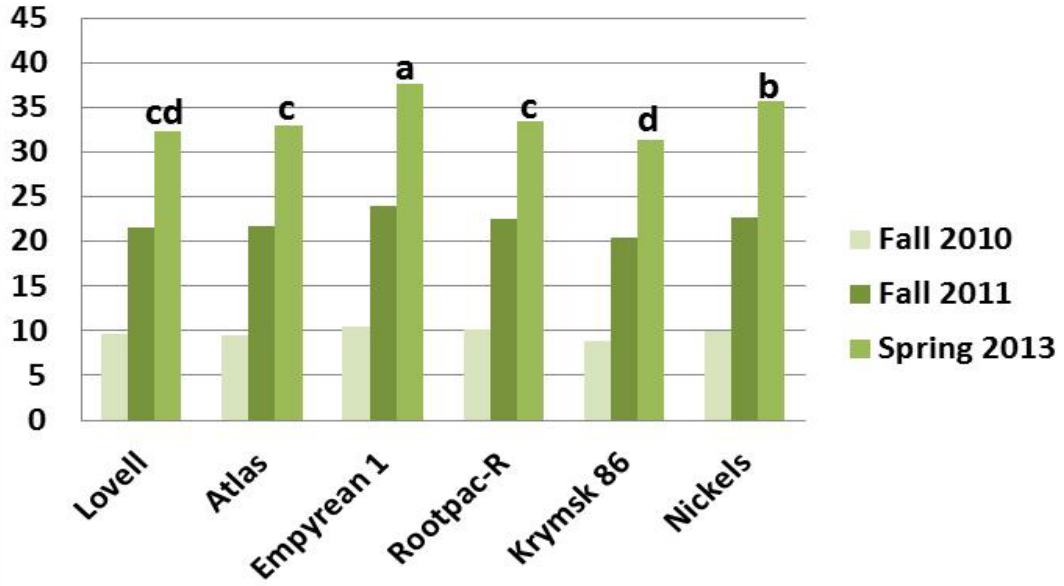

Figure 1. Trunk circumference of Nonpareil almond in centimeters after three growing seasons.

Yield data was collected starting in the third leaf. Fourth leaf Nonpareil yields were heaviest in trees on Empyrean 1 rootstock and lightest on Rootpac-R and Krymsk 86 rootstocks. Other rootstocks produced intermediate yields (**Table 1**). This is primarily a reflection of differences in tree size related to the vigor of the rootstock.

Table 1. Yield of Nonpareil almond on six rootstocks planted in Durham, California.

	Lbs. kernel per tree	
Rootstock	3rd Leaf	4th Leaf
Lovell	0.65 cd	9.22 cd
Atlas	1.00 a	10.53 ab
Empyrean 1	0.61 d	11.69 a
Rootpac-R	0.79 bcd	9.07 d
Krymsk 86	0.93 ab	9.00 d
Nickels	0.85 abc	10.28 bc

* Replants are not included in the calculations for per tree yield. Values followed by the same letters are not significantly different from one another at P< 0.05 using Fisher's least significant difference (LSD) procedure.

Performance of 14 Almond Rootstocks in a Sandy Location Irrigated with Well Water.

Project Leader: David Doll, Farm Advisor, UCCE - Merced County

Cooperating personnel: Matt Jones and Andrew Ray, Merced Research Associates, UCCE – Merced County
Glen Arnold and Craig Arnold, Arnold Farms

Objective:

To compare rootstock performance based on growth, nematode counts, tissue sampling, stem water potential, and yield on a test site that has sandy, low exchange-capacity soils with shallow areas and hardpans, as well as presence of ring, root-knot, and root-lesion nematodes, and is irrigated with high sodium and high nitrate groundwater. 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 2011 on a site with Atwater Sand in Winton, CA. The trial compares the performance of Nonpareil on 14 rootstocks, and the performance of Fritz and Monterey on seven rootstocks (**Table 1**). Each of 6 replicate blocks is comprised of six trees of each rootstock and variety combination. Many of the rootstocks selected for the trial are peach/almond hybrids (P/A-Hybrids), as the grower developed an interest in P/A-Hybrids after participating 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, which were planted in April 2011. Trees are spaced at 22'x18' and irrigated using double line drip.

Methods:

Soil mapping was done using Veris Electrical Conductivity Mapping (Strategic Farming). Differences in soil zones were identified (**Figure 1**), analyzed (**Table 2**), and used to design experimental blocks. Trunks were measured shortly after planting and subsequently after the end of each growing season. Stem water potential (SWP) was measured on three trees of each Nonpareil rootstock within blocks 1-3 using established UC procedures. Each of the three blocks was measured four times throughout the season, for a total of 12 SWP measurements for each rootstock. Nematode samples were collected in October 2012 and 2013 and sent for analysis by Nematodes, Inc. (Selma, CA). Observations of bloom percentage as influenced by variety and rootstock were taken on February 24, 2012, March 4th, 2013, and February 14, 2014.

Results and Discussion:

Initial analysis indicated soil quality was suitable for almond production (**Table 2**), though differences in soil nutrient and water holding capacities (as measured by soil EC) were observed.

Within each scion variety, tree growth (caliper diameter) varied among rootstocks. Among Nonpareil – grafted rootstocks, Emyrean-1, Floridaguard x Alnem, and TemproPac showed the most total growth since planting, while Nemaguard, Krymsk-86, and Atlas have grown the least among those planted in January 2011 (**Table 3**). Cadaman and Cornerstone grew the least overall, likely cause by delayed planting (**Table 3**). Nonpareil – grafted rootstocks exhibited mostly similar growth rates in the 2013 season, though TemproPac had significantly greater growth than Atlas and Nemaguard (**Table 3**). Rootstocks grafted to Fritz grew at similar rates in the 2013 growing season (**Table 4**), while Hansen 536 and Red Titan III grew significantly more in than Atlas and Nemaguard in 2013 when grafted to Monterey (**Table 5**). On both Fritz and Monterey, Empyrean-1, Hansen, and Viking rootstocks showed significantly greater total growth since planting (**Tables 4 and 5**).

2013 produced the first harvestable crop for comparison of yields among rootstocks. Overall yields were highest among rootstocks grafted to Monterey (**Table 6**). Yield varied to some degree among rootstocks within scion variety. On Nonpareil, Atlas showed significantly higher yields than BH5, Cadaman, Krymsk-86, and Cornerstone (**Table 6**). Yields of Atlas were significantly higher than BH5 on Fritz, but were otherwise similar among rootstocks grafted to this scion. On Monterey, Empyrean-1 showed significantly greater yields than Viking, BH5, and Red Titan III. Empyrean on Monterey also exhibited the highest yield among all rootstock x scion combinations.

SWP measurements in 2013 were greater (more negative) from baseline than in previous years, indicating trees were more stressed in 2013. SWP off baseline varied less among rootstocks on Nonpareil in 2013 than in 2012, with Krymsk-86 and RootPac(R) showing significantly greater stress than Atlas, Floridaguard x Alnem, and Hansen-536 (**Table 7**).

Differences in bloom period, as determined by the proportion of open flowers on a given date, were observed among rootstocks and scion varieties (**Tables 8 - 10**). In 2014, Fritz on all rootstocks had substantially lower percent bloom on the observation date, suggesting Fritz experienced delayed bloom relative to Nonpareil and Monterey at this site. Fritz trees were not delayed compared to other cultivars in 2012. Nonpareil on Hansen 536 this year exhibited advanced bloom compared to Nonpareil on BB106, Nemaguard, RootPac(R), and TemproPac, whereas Nonpareil on Empyrean-1 and Hansen 536 bloomed earlier than Nonpareil on Nemaguard, RootPac(R), TemproPac, Red Titan III, BH5, and Floridaguard x Alnem in 2012 (**Table 8**). There were no significant differences among rootstocks on Fritz in 2014, but Fritz on Empyrean-1 and Hansen 536 bloomed earlier (higher % bloom) than on other rootstocks in 2012 (**Table**

9). Monterey on Empyrean-1 and Hansen 536 also had higher percent bloom than on Nemaguard in 2014, and higher percent bloom than Nemaguard, Red Titan III, and BH5 in 2012 (**Table 10**).

Nematode populations typically take 2-3 years after fumigation to reestablish in the soil. Previous sampling indicated no detectable nematodes counts among all rootstocks and blocks. However, sampling in late 2013 showed the first detectable presence of root-lesion nematodes in soils around Krymsk-86 and Cornerstone rootstocks (data not shown). Nematode counts will be monitored closely in subsequent 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 additional rootstocks were planted on Nonpareil only. Asterisk indicates rootstocks planted in April 2011 due to nursery availability.

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

Table 2. Soil analysis of the six blocks established within the rootstock trial. Samples were collected in October, 2010 and analyzed by the UC ANR Analytical Laboratory.

Block	Soil Classification	Organic %	P - PPM	K PPM	Mg PPM	Ca PPM	Na PPM	pH	CEC meq/100	Base Saturation % K	Mg	Ca	H	Na
1	Sandy Loam	0.7	16	68	264	1172	85	7.0	8.6	2	25.4	68.3	0	4.3
2	Sandy Loam	0.5	36	63	141	668	39	6.6	5.1	3.1	22.6	64.9	6	3.3
3	Loamy Sand	0.4	55	56	73	366	16	6.7	2.8	5.2	21.8	66	4.5	2.6
4	Loamy Sand	0.4	72	52	62	290	25	6.0	2.6	5.2	19.7	55.9	15	4.2
5	Loamy Sand	0.5	33	58	81	377	25	6.5	3.0	4.9	62.1	62.1	7.5	3.6

Table 3. Mean changes in trunk caliper (mm) in 2011, 2012, 2013 and total change in caliper since planting of Nonpareil scions grafted to 14 different rootstocks. Measurements with different letters indicate significant differences at p<0.05 (ANOVA and Tukey-Kramer HSD). Asterisk denotes treatments planted as potted trees in mid-April, later than other treatments.

Rootstock, cv Nonpareil	2011	2012	2013	Total
Atlas	44.5 AB	46.5 BC	31.1 BC	122.1 D
BB106	46.8 AB	47.4 BC	37.7 AB	131.9 ABC
BH5	42.5 BC	46.4 BC	36.6 AB	125.2 CD
Cadaman *	27.3 D	42.1 C	37.4 AB	106.8 F
Cornerstone*	30.5 D	45.2 BC	32.3 ABC	108.0 EF
Empyrean-1	46.2 AB	55.5 A	35.3 ABC	137.2 A
Floridaguard x Alnem	43.5 ABC	55.2 A	37.8 AB	136.5 A
Hansen	45.3 AB	53.4 AB	37.1 AB	135.8 AB
Krymsk-86	41.5 ABC	45.6 BC	31.4 ABC	118.5 DE
Nemaguard	42.9 ABC	50.5 AB	26.6 C	120.1 D
Red Titan III	38.8 C	46.1 BC	40.2 AB	125.1 CD
RootPacR	42.7 ABC	45.3 BC	32.5 ABC	120.6 D
TemproPacR	44.7 AB	51.1 AB	41.6 A	137.4 A
Viking	46.9 A	46.6 BC	34.1 ABC	127.6 BCD

Table 4. Mean changes in trunk caliper (mm) in 2011, 2012, 2013 and total change in caliper since planting of Fritz scions grafted to 7 different rootstocks. Measurements with different letters indicate statistically significant differences at p<0.05 (ANOVA and Tukey-Kramer HSD). Asterisk denotes treatments planted as potted trees in mid-January.

Rootstock cv Fritz	2011	2012	2013	Total
Atlas	45.5 A	50.1 AB	40.1 A	135.7 AB
BH5*	36.6 B	43.7 B	43.1 A	123.4 C
Empyrean-1	43.8 A	53.0 A	41.4 A	138.2 A
Hansen	44.9 A	53.9 A	44.7 A	143.6 A
Nemaguard	43.9 A	45.9 B	38.2 A	128.1 BC
Red Titan III	42.0 A	43.2 B	38.2 A	123.4 C
Viking	45.2 A	55.7 A	39.1 A	140.0 A

Table 5. Mean changes in trunk caliper (mm) in 2011, 2012, 2013 and total change in caliper since planting of Monterey scions grafted to 7 different rootstocks. Measurements with different letters indicate statistically significant differences at p<0.05 (ANOVA and Tukey-Kramer HSD). Asterisk denotes treatments planted as potted trees in mid-January.

Rootstock cv Monterey	2011	2012	2013	Total
Atlas	47.1 ABC	50.1 B	37.2 BC	134.4 B
BH5*	41.4 D	48.3 B	40.0 ABC	129.7 B
Empyrean-1	49.4 A	55.7 A	42.4 AB	147.6 A
Hansen	47.3 ABC	56.4 A	46.2 A	149.9 A
Nemaguard	44.1 BCD	47.9 B	35.5 C	127.5 B
Red Titan III	42.7 CD	47.6 B	44.4 A	134.6 B
Viking	48.8 AB	52.0 AB	43.6 AB	144.4 A

Table 6. Mean 2013 yield (kernel lbs. / acre) for Nonpareil, Fritz and Monterey scions grafted to different rootstocks. Measurements with different letters indicate statistically significant differences at p<0.05 (ANOVA and Tukey-Kramer HSD). Asterisk denotes treatments planted as potted trees in mid-April.

Rootstock, cv Nonpareil	Nonpareil	Fritz	Monterey
Atlas	536.8 A	435.6 A	752.4 AB
BB106	398.2 AB		
BH5	348.7 BC	223.3 B	562.1 BC
Cadaman *	330 BC		
Cornerstone*	209 C		
Empyrean-1	503.8 AB	377.3 AB	828.3 A
Floridaguard x Alnem	375.1 ABC		
Hansen	442.2 AB	405.9 AB	624.8 ABC
Krymsk-86	321.2 BC		
Nemaguard	398.2 AB	316.8 AB	629.2 ABC
Red Titan III	357.5 ABC	269.5 AB	
RootPacR	369.6 ABC		
TemproPac	360.8 ABC		
Viking	477.4 AB	429.0 AB	591.8 BC

Table 7. Stem water potential measurements sampled from 14 rootstocks grafted to Nonpareil for the 2011-2013 growing seasons. Number reported is difference from baseline determined from temperature and humidity of the day measurements were taken. Measurements with different letters indicate statistically significant differences at p<0.05 (ANOVA and Tukey-Kramer HSD).

Rootstock (Nonpareil Scion)	2011 SWP off Baseline Baseline (bars)	2012 SWP off Baseline (bars)	2013 SWP off Baseline (bars)
Atlas	-1.49 AB	-0.98 ABCD	-2.45 A
BB106	-1.86 AB	-1.48 CDE	-3.38 AB
BH5	-1.94 AB	-1.10 ABCD	-2.68 AB
Cadaman	-2.20 AB	-1.59 DE	-2.82 AB
Cornerstone	-2.07 AB	-1.30 BCDE	-3.91 AB
Empyrean-1	-2.06 AB	-0.43 A	-3.07 AB
Flor x Alnem	-1.17 A	-0.96 ABCD	-2.01 A
Hansen	-1.57 AB	-1.34 BCDE	-1.86 A
Krymsk-86	-2.54 B	-1.20 BCDE	-4.94 B
Nemaguard	-1.62 AB	-0.86 ABCD	-2.69 AB
Red Titan	-2.19 AB	-1.60 DE	-3.49 AB
RootPacR	-2.54 B	-1.76 E	-4.96 B
TemproPac	-2.04 AB	-0.79 ABC	-2.92 AB
Viking	-1.52 AB	-0.67 AB	-2.68 AB

Table 8. Mean estimated percent bloom for three seasons among rootstocks grafted to 'Nonpareil'. Bloom period in 2013 was too compact to reliably determine % bloom differences among rootstocks. Measurements with different letters indicate statistically significant differences at p<0.05 (ANOVA and Tukey-Kramer HSD of arcsin transformed bloom percentages).

Rootstock, cv Nonpareil	2012	2013	2014
Atlas	43% DEF	100%	34% ABC
BB106	63% BCD	100%	25% C
BH5	43% DEFG	100%	32% ABC
Cadaman	22% GHI	100%	29% ABC
Cornerstone	11% I	100%	30% ABC
Empyrean-1	76% A	100%	53% AB
Flor x Alnem	38% DEFGH	100%	35% ABC
Hansen	63% ABC	100%	56% A
Krymsk-86	7% I	100%	33% ABC
Nemaguard	54% CDE	100%	23% C
Red Titan	28% FGHI	100%	28% ABC
RootPacR	23% HI	100%	28% BC
TemproPac	35% EFGH	100%	31% BC
Viking	74% AB	100%	28% ABC

Table 9. Mean estimated percent bloom for three seasons among rootstocks grafted to Fritz. Bloom period in 2013 was too compact to reliably determine % bloom differences among rootstocks. Measurements with different letters indicate statistically significant differences at p<0.05 (ANOVA and Tukey-Kramer HSD of arcsin transformed bloom percentages).

Rootstock, cv Fritz	2012	2013	2014
Atlas	31% B	100%	6% A
BH5	12% C	100%	5% A
Empyrean-1	66% A	100%	11% A
Hansen	55% A	100%	12% A
Nemaguard	28% BC	100%	3% A
Red Titan III	26% BC	100%	5% A
Viking	36% B	100%	4% A

Table 10. Estimated percent bloom for three seasons among rootstocks grafted to Monterey. Bloom period in 2013 was too compact to reliably determine % bloom differences among rootstocks. Measurements with different letters indicate statistically significant differences at p<0.05 (ANOVA and Tukey-Kramer HSD of arcsin transformed bloom percentages).

Rootstock, cv Monterey	2012	2013	2014
Atlas	42% BC	100%	36% AB
BH5	21% D	100%	28% AB
Empyrean-1	71% A	100%	48% A
Hansen	64% AB	100%	53% A
Nemaguard	27% D	100%	18% B
Red Titan III	33% CD	100%	31% AB
Viking	53% AB	100%	27% AB

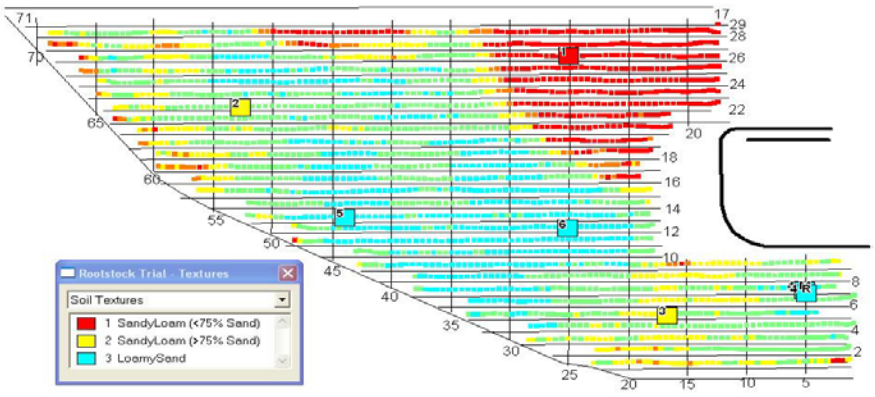

Figure 1. Soil electrical conductivity (EC) map of the rootstock plot. Red areas indicate heavier soil, while blue indicates lighter, coarser soil. EC mapping provides the ability to distinguish soil variations that are not detectable from viewing soil surveys. Differences in EC indicate different water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

Field Evaluation of Plum & Plum Hybrid Rootstocks for Tolerance to *Armillaria* spp. in a Flood-Irrigated, Sandy Loam, Replant Location

Project Leader: Roger Duncan, Farm Advisor, UCCE - Stanislaus County

Objective:

To evaluate seven alternative rootstocks for field tolerance to *Armillaria mellea* (oak root fungus, ORF) and compare them to Nemaguard and Marianna 2624.

Interpretive Summary:

- Despite rampant oak root fungus disease in the previous orchard, few signs of the disease are apparent in the trial.
- One tree, on Tetra rootstock, showed signs of ORF infection in 2012 but has shown no ill effects of the disease even after three years.
- Trees on Viking rootstock are the largest while trees on Tetra, Hiawatha and Empyrean 2 (Penta) are the smallest.

Background:

Most Armillaria rootstock trials have been conducted in relatively heavy soils with sprinkler or micro-irrigation systems. However, rootstocks that may grow acceptably in heavy soil sometimes perform poorly under sandy, flood-irrigated conditions. Soil type and irrigation method may also influence disease susceptibility.

Materials & Methods:

This replicated trial was planted in 2007 in a flood-irrigated replant location which was fallowed for one year and fumigated with Vapam® prior to planting. The soil is a Hanford sandy loam. The trial is located in an area where the former orchard (on Nemaguard) was ravaged by *Armillaria mellea*. Experimental rootstocks include Ishtara, Krymsk 86, Hiawatha, Empyrean 2, Tetra, Marianna 40 and Viking. Tree performance is compared against standards Nemaguard and Marianna 2624.

Results and Discussion:

Although the previous orchard was ravaged by oak root fungus disease, only one tree in this trial has shown signs of infection by Armillaria after eight years. One tree on Tetra has been infected for at least two years (evidenced by gumming at the base, obvious Armillaria mycelium and mushroom growth at the base of the tree in the winter) but so far shows no obvious ill effects of the disease. This may be evidence of some level of tolerance by the Penta rootstock as a tree on Nemaguard would have likely died by now.

So far, trees on Viking have the largest trunk circumference while trees on Tetra, Hiawatha and Empyrean 2 are the smallest (see 12-HORT4-Duncan). Krymsk 86 is moderate in size, very similar to Nemaguard in this trial. It is interesting to note that the difference in trunk circumference between the Butte and Padre trees is minimal for trees on Viking, Nemaguard, Krymsk 86 and M-40 while there is a substantial difference between the two varieties on Hiawatha, Empyrean 2, Tetra and Marianna 2624. It is unknown whether this infers less compatibility with the Butte variety with these four rootstocks (it is known that Butte is less compatible on Marianna 2624 than is Padre). In 2010, signs of union mild etch were evident in two Butte trees on M 2624, but not on other plum rootstocks. No signs of mild etch has been observed on any tree since.

Field Evaluation of Almond Rootstocks for the West Side of the North San Joaquin Valley.

Project leaders: Roger Duncan, Farm Advisor, UCCE - Stanislaus County
Brent Holtz, UCCE - San Joaquin County

Objective:

Evaluate 16 almond rootstocks for their performance in a heavy, high pH soil irrigated with alkaline water.

Interpretive Summary:

- In general, trees on peach x almond hybrid rootstocks are the largest, with the exception of trees on Paramount which are significantly smaller than the rest of the PxA hybrids.
- Trees on Empyrean 1 and Rootpac R are as large as trees on peach x almond hybrid rootstocks.
- Trees on Lovell and Krymsk 86 are among the smallest in the trial.
- Trees on Lovell rootstock have had a significantly higher incidence (number of affected trees) of Verticillium wilt disease expression than other rootstocks while Hansen has the highest severity (amount of affected canopy).
- Atlas and HM2 appear to be highly tolerant of Verticillium wilt and have shown no signs of Verticillium wilt in this trial.

Background:

Almond planting continues to expand on the west side of the North San Joaquin Valley, replacing lower value row crops. In contrast to the more traditional tree growing areas of the east side with low pH, nematode infested, sandy loam soils, the west side soil is moderately heavy with higher salt levels and the pH is often 7.5 or higher. The irrigation

water is typically high in bicarbonates, boron and sodium. Due to their lack of experience or data on alternative rootstocks for this area, most growers' plant on Nemaguard which is ill suited for Westside growing conditions. As a result, growth is reduced, leaves often show signs of marginal salt burn by the end of the season and trees likely have reduced yield potential. The objective of this trial is to monitor the performance of Nonpareil almond trees grown on sixteen rootstocks in order to find a better alternative to Nemaguard for the Westside of the North San Joaquin Valley.

Materials and Methods:

In this trial, the performances of sixteen rootstocks are being tested under "typical" west side conditions. On December 21, 2011, the trees were planted in a randomized complete block design with six replicates of all rootstocks in a commercial orchard off Highway 33 near the town of Westley. Trees were planted at a spacing of 16' x 20' (136 trees per acre). All tested rootstocks have Nonpareil as the scion. Pollinizer varieties are Carmel and Monterey. The soil is a Zacharias clay loam with moderately high soil pH (7.5), high magnesium (555 ppm), high boron (1.7 ppm) and moderate soluble salts (1.3 mmhos / cm). The orchard is irrigated primarily with West Stanislaus Irrigation District water, which is blended with tail water from area fields and water from the San Joaquin River. This water is often high in salts, especially towards the end of the summer. Depending on the availability of district water, irrigation is supplemented with well water, which has moderately high salt and pH. The field has a long history of melons, tomatoes and other row crops which have led to expression of Verticillium wilt disease in this trial. Preplant soil samples indicated no detectable rootknot or ring nematodes. Rootstock parentage includes peach (*P. persica*), intra-species peach hybrids, hybrids of peach x almond, peach x plum, almond x plum and complex hybrids that include peach, almond, plum and apricot. Rootstocks tested in this trial include:

- Lovell — *P. persica*
- Nemaguard — *P. persica*
- Empyrean 1 — *P. persica x P. davidiana*
- Avimag — *P. persica x P. davidiana*
- HBOK 50 — Harrow blood x Okinawa peach
- Hansen — *P. dulcis x P. persica*
- Brights #5 — *P. dulcis x P. persica*
- BB 106 — *P. dulcis x P. persica*
- Paramount — *P. dulcis x P. persica*
- Flordaguard x Alnem — *P. persica* x Israeli bitter almond
- PAC9908-02 — (*P. dulcis x P. persica) x P. persica*
- HM2 + Hansen — (*P. dulcis x P. persica)* x Monegro (*P. dulcis* × *P. persica*)
- Viking — peach x plum x almond x apricot
- Atlas — peach x almond x plum x apricot
- Krymsk 86 — *P. cerasifera* x *P. persica*
- Rootpac R — *P. dulcis* x plum

Results & Discussion:

Tree Growth. In general, trees on peach x almond hybrid rootstocks (PAC9908-02, FxA, HM2, BB 106 & Hansen) are the largest, with the exception of trees on Paramount which are significantly smaller than the rest of the PxA hybrids (**Table 1**). Empyrean 1 and Rootpac R are as large as the peach x almond hybrids. Lovell and Krymsk 86 are among the smallest trees in the trial. Brights 5, Avimag (a.k.a. Cadaman) and HBOK 50 were planted as potted trees and started out smaller than the other trees which were planted as bare root trees.

Table 1. Trunk Caliper of Sixteen Rootstocks. Summer of Second Leaf.

	Trunk Circumference (cm)
PAC9908-02	37.7 a
Empyrean 1	36.8 a
Flordaguard x Alnem	36.3 a
Rootpac R	36.1 a
HM2	35.8 a
BB 106	35.8 a
Hansen	35.7 a
*Brights 5	33.2 b
Nemaguard	33.1 b
Atlas	32.9 b
Viking	32.8 b
*HBOK 50	32.6 b
Paramount	31.9 bc
Krymsk 86	31.8 bc
Lovell	31.5 bc
*Avimag	30.2 c

*These trees were potted and were therefore younger and smaller than the bareroot trees at planting time.

Expression of Verticillium wilt. As mentioned above, this field had a long history of tomatoes, melons and other row crops that serve as hosts to *Verticillium dahlia*, the fungal pathogen that causes Verticillium wilt. In the spring of 2013 (second leaf), trees on some rootstocks began showing shoot dieback and wilt symptoms characteristic of this disease (see 12-HORT4-Duncan). Symptoms were expressed again in 2014 (3rd leaf). As in the previous year, more trees on Lovell rootstock (40.0%) expressed wilt and dieback symptoms than any other rootstock (**Table 2**). Incidence of wilt was also high for trees on Avimag (Cadaman), Hansen and F x A rootstocks. The severity of wilt expression (percent of canopy affected by wilt) was significantly higher on Hansen (12.6%) than on any other rootstock. No signs of Verticillium wilt have ever been observed on Atlas or HM2.

Table 2. Incidence and Severity of Verticillium Wilt Symptoms Expressed in Nonpareil Almonds Grown on Various Rootstocks. June 2014 (3rd leaf).		
	Incidence (% trees with wilt symptoms)	Severity (average % of canopy affected in trees with symptoms)
Lovell	40.0 a	6.1 b
Avimag	33.3 ab	2.0 b
Hansen	23.3 abc	12.6 a
F x A	20.0 abcd	5.7 b
Paramount	17.5 bcd	3.7 b
Empyrean 1	16.7 bcd	2.2 b
Viking	10.0 cd	3.8 b
Nemaguard	10.0 cd	2.3 b
HBOK 50	6.7 cd	1.3 b
BB 106	6.7 cd	2.1 b
Rootpac R	6.7 cd	0.2 b
Brights 5	3.3 cd	3.3 b
PAC9908-02	3.3 cd	0.2 b
Krymsk 86	3.3 cd	0.2 b
Atlas	0 d	0 b
HM2	0 d	0 b

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

Project Leader: Roger Duncan, Farm Advisor; UCCE - Stanislaus County

Interpretive Summary:

- In general, the largest trees have had the highest yields.
- An exception is Atlas which is a moderately sized tree but often produces yields similar to more vigorous rootstocks.
- Trees on the peach x almond hybrids have higher cumulative yields based on six years of collected yield data:5,268 6,160 more Nonpareil kernel pounds than trees on Nemaguard; and 7,167 – 8,442 more Carmel kernel pounds than trees on Nemaguard.
- Nemaguard, Lovell, Guardian, Atlas and Krymsk 86 had significantly higher leaf levels of sodium and chloride than other rootstocks in the trial and expressed more toxicity injury (leaf burn).
- Sodium leaf levels were very low in Cornerstone, Paramount, Adesoto, Hansen and Empyrean 1.
- Due to high pH of underlying soil layers, leaves from trees on Lovell, Nemaguard, Guardian and Krymsk 86 had lower leaf chlorophyll measurements and were yellower than trees on other rootstocks.

Materials & Methods:

In January, 2003, a replicated field trial was planted in a commercial almond orchard to test the performance of sixteen rootstocks budded with Nonpareil and Carmel scions in an unfumigated, sandy loam, replant location. An old almond orchard on Nemaguard rootstock was removed one year prior to replanting. Tree sites were backhoed with an excavator in the fall prior to planting but were not fumigated. The soil is a Hanford sandy loam and had no particular chemical or physical soil problems (pH = 6.8; ECe = 0.9 dS/m; CEC = 5.2) at planting time. The orchard is flood irrigated primarily with excellent quality district water. The orchard spacing is 17' x 21' (122 trees per acre). Rootstocks and their parentage are listed in **Table 1** below.

Beginning in 2010, irrigation has been supplemented with well water applied through microsprinklers. Soil tests in 2013 indicate that the soil has become more alkaline than at planting time eleven years earlier. Current tests show that the upper 18 inches have a pH of 6.9 – 7.3, E.C. is 1.1 dS/m, the SAR is 1.5 and sodium is 2.4 – 3.3 meq/L. The lower soil profile (18-36 inches) has a pH of 7.4 - 7.6 with similar E.C. and SAR values as the upper profile. Over the past three years, many trees in the trial are showing severe signs of salt burn and chlorosis.

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

Rootstock	Parentage	Origin
Nemaguard	Peach (*P. persica*)	USA
Lovell	Peach 1882 processing peach selection (*P. persica*)	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*)	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
Atlas	Complex hybrids containing Nemaguard, Jordanolo almond, plum and apricot	Zaiger Genetics
Viking		Zaiger Genetics

Results and Discussion:

Several years of data including rootstock effects on tree size, yield, bloom time, hull split and root suckering have been reported in previous Almond Board of California research reports. This current report includes 2013 yield (11th leaf), leaf chlorophyll readings and

leaf analyses for sodium and chloride.

2013 yields were tremendously high in this test orchard following a terrible crop in 2012 due to frost damage. Calculated yields per acre correlate very strongly with tree size. The most vigorous rootstocks tend to have the highest per acre yields because the canopy developed more rapidly and probably now occupy area that smaller rootstocks are now unable to fill. Per acre yields of less vigorous rootstocks might be increased early in the life of an orchard by planting trees more densely. Nonpareil trees on peach x almond hybrid rootstocks have cumulative yields from 5,268 to 6,160 kernel pounds more than Nonpareil trees on Nemaguard during the six years that yield data have been collected in this trial (**Table 2**). The Carmel variety has benefitted even more from being on a vigorous rootstock. Cumulatively, Carmel trees on PxA hybrid rootstocks have yielded 7,167 – 8,442 more kernel pounds then trees on Nemaguard during the six years of yield collection in this trial.

Trees on the plum rootstocks (Empyrean 2, Empyrean 101 and Julior) are very small and may not be well suited for a sandy loam soil, especially under flood irrigation. They probably would have significantly lower yields than the peach x almond hybrid rootstocks even if they were planted very densely. Krymsk 86, a peach x plum hybrid, appears to be slightly less vigorous than Lovell under these growing conditions.

Table 2. Yield (kernel pounds per acre) of Nonpareil & Carmel Almond Trees in 2013 (11th Leaf) & Cumulatively (4th thru 8th + 11th Leaf).

	Nonpareil		Carmel	
	2013 (11th leaf)	Cumulative	2013 (11th leaf)	Cumulative
Paramount	--	--	5552 a	22,627
Nickels	6706 a	21,425	5158 ab	23,902
Cornerstone	5786 b	20,246	--	--
Hansen 536	5420 bc	20,533	4544 abc	21,959
Empyrean #1	5295 bcd	19,489	--	--
Avimag	5069 bcde	17,128	4376 bc	19,162
Atlas	4759 cde	17,187	5167 ab	21,307
Lovell	4615 de	15,512	3576 c	15,062
Viking	4591 de	16,038	4379 bc	17,733
Nemaguard	4381 ef	15,265	3575 c	15,460
Guardian	3851 f	15,124	3723 c	16,114
Krymsk 86	3653 fg	10,839*	--	--
Empyrean 101	3085 gh	9,113	--	--
Empyrean 2	2975 h	8157*	2370*	--
Julior	--	--	1422*	--

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

Beginning around 2011, some trees within the trial began to show late season signs of salt toxicity. This may have been due in part to a change from flood irrigating with district water to sprinkler irrigating with ground water and/or the influence of the

underlying alkaline soil layer. Symptoms were much more severe on the Carmel variety, especially on the peach rootstocks. In September, 2013, leaves were collected from nonbearing spurs and sent to the UC ANR Lab for sodium and chloride analyses (**Table 3**). Trees on the peach rootstocks (Nemaguard, Lovell & Guardian), Atlas and Krymsk 86 had highly toxic levels of sodium, ranging from 0.60 – 0.99 percent. Avimag, Julior, Empyrean 2, Viking and Nickels had intermediate sodium levels (0.28 – 0.38 percent) while Hansen, Paramount, Empyrean 1, Cornerstone and Empyrean 101 had low leaf levels of sodium (0.04 – 0.09 percent). Nemaguard, Lovell and Guardian, as well as Empyrean 2 had very high levels of leaf chloride (0.41 – 0.53 ppm) while Hansen, Paramount, Empyrean 1, Cornerstone and Empyrean 101 had low chloride leaf levels (0.04 – 0.07 percent).

Table 3. Leaf Levels of Sodium and Chloride in Nonpareil & Carmel Almonds on Various Rootstocks. September, 2013

	Carmel		Nonpareil	
	% Sodium	% Chloride	% Sodium	% Chloride
Nemaguard	0.99 a	0.51 a	0.76 a	0.28 b
Atlas	0.94 a	0.29 b	-	-
Guardian	0.76 a	0.41 a	-	-
Lovell	0.70 a	0.50 a	-	-
Cadaman	0.38 b	0.25 b	-	-
Julior	0.35 b	0.16 bc	-	-
Empyrean 2	0.30 b	0.41 a	0.34 b	0.53 a
Viking	0.29 b	0.21 bc	-	-
Nickels	0.28 b	0.15 cd	-	-
Hansen	0.09 c	0.07 d	-	-
Paramount	0.04 c	0.05 d	-	-
Empyrean 1	-	-	0.09 c	0.07 c
Cornerstone	-	-	0.04 c	0.05 c
Krymsk 86	-	-	0.60 a	0.32 b
Adesoto	-	-	0.06 c	0.04 c
July Critical Leaf Level			< 0.25	<0.30

In 2014, many trees in the trial had very yellow leaves which resembled lime induced chlorosis. The problem appeared to be much worse on the peach rootstocks Lovell, Nemaguard and Guardian. In May, 2014, the chlorophyll status of the trees was measured with a SPAD 502 Plus chlorophyll meter (Spectrum Technologies, Inc). Leaves of Nonpareil trees on Lovell, Nemaguard, Guardian and Krymsk 86 had significantly lower chlorophyll readings than all other rootstocks (**Table 4**). Hansen, Nickels, Paramount and Empyrean 2 had the greenest Nonpareil leaves.

Table 4. Chlorophyll Status of Leaves from Nonpareil and Carmel Almond Trees Grown on Various Rootstocks[1]. May, 2104.		
	Nonpareil	Carmel
Hansen	38.4 a	39.8 a
Nickels	37.3 ab	39.6 ab
Paramount	37.2 abc	39.7 a
Empyrean 2	37.0 abc	38.0[2]
Cornerstone	36.8 bcd	
Empyrean 101	36.6 bcd	
Empyrean 1	36.4 bcd	37.6[2]
Atlas	36.1 bcd	36.1 c
Avimag	35.8 cd	38.3 b
Viking	35.4 d	36.4 c
Krymsk 86	34.0 e	
Guardian	33.3 e	35.0 cd
Nemaguard	33.2 e	34.4 d
Lovell	33.1 e	32.8 e

[1]Leaf chlorophyll status was determined by using a Minolta SPAD 502 chlorophyll meter.
[2]Carmel trees on Empyrean 1 & Empyrean 2 were not fully replicated and were not included in the statistical analyses.

Effects of eight almond rootstocks on Nonpareil tree growth grown on marginal soil high in boron

Project Leader: Franz Niederholzer, Farm Advisor, UCCE – Colusa/Sutter/Yuba Counties

Project Cooperators: Carolyn DeBuse, former Farm Advisor, UCCE - Solano/Yolo Counties
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Objectives:

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

Interpretive Summary:

As the almond industry expands in California, growers are increasingly planting new orchards on marginal soil using lower quality irrigation water. Almonds are generally more tolerant of drought and shallow soils than other tree crops, but in the Sacramento Valley the marginal soil textures are often poorly drained clays. These heavier soils can pose a risk to root and, ultimately, tree health. In addition, the soils and irrigation waters in Yolo County are often high in boron.

These soil limitations are not unique to Yolo County. Heavy soils are found throughout the Sacramento Valley. In some areas of the west side of the San Joaquin Valley, soil and water boron levels are so high that they prohibit agriculture. The plot chosen for this trial tests both of these soil limitations – fine texture and high boron -- in the evaluation of eight almond rootstocks.

Previous research and observational data identified seven rootstocks that may be more tolerant of high boron than Lovell peach, traditionally the most commonly planted almond rootstock in the Sacramento Valley. They are Hansen 536, Nickels, Flordaguard x alnem hybrid (FXA), Krymsk 86, Brights-5, Rootpac-R, and Viking. This study assesses potential differences in boron tolerance between these rootstocks and evaluates their yield 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. The soil is classified as Marvin silty clay loam (Storie Index (CA) = 65). Soils in this series are listed as moderately well to poorly drained. The main crop suitable for growing on this soil and listed in the official soil series description [https://soilseries.sc.egov.usda.gov/OSD_Docs/M/MARVIN.html] are grain, field crops, sugar beets, alfalfa and rice – no perennial crops. Irrigation water boron concentrations range between 1-3 ppm B.

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. Trees were planted at a spacing of 22’ across the row and 18’ down the row on 4’ long islands. 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.

In 2013, the orchard was in its 3rd leaf. Leaf nutrient assessment was done in July by collecting and bulking leaves from all 5 trees in each replicate into a single sample. Hull samples were similarly taken (bulked for each replicate) at harvest. Samples were analyzed for boron by UC Davis Analytical Lab. Yield per acre was calculated following harvest of 5-tree replicates by the grower.

Hull samples indicate excessive boron in all rootstock treatments (**Table 1**) in 2013. Tree boron status is considered excessive when hulls, sampled at harvest, exceeds 200 ppm boron on a dry weight basis. Hull levels were as much as 3x that threshold (**Table 1**). Treatment leaf B levels were not significantly different (**Table 1**), and were at levels considered “adequate”. These data highlight the need to use hull sampling at harvest, not July leaf samples, to accurately assess almond orchard boron status.

Significant differences in average yield per acre were measured between rootstocks in 2013, the first harvested crop (**Table 1**). Peach x almond hybrids Brights-5 and Nickels produced the highest average yields per acre while Lovell peach and Krymsk 86 rooted trees produced relatively lower yields. High and low replicate yield per acre are presented for each treatment to illustrate variability among rootstocks in this study (**Table 1**).

Table 1. 2013 July average boron leaf concentration (ppm B on a dry weight basis), hull boron (ppm B on a dry weight basis) at harvest, and average yield (kernel lbs/acre) of 3rd leaf Nonpareil almond grafted on one of 8 different rootstocks. Letters indicate the significant differences between treatment means or medians in separate columns at the level p≤ 0.05 using Duncan's Multiple Range test. The orchard was planted in February, 2011. Planting density = 110 trees/acre (18' x 22').

Rootstock	Leaf boron (ppm B)	Hull boron (ppm B)	Ave yield (kernel lb/acre)	Hi-Lo yield range (kernel lbs/acre)
Brights 5	64 a	590 abc	298 a	267-354
Nickels	62 a	519 a	280 a	220-335
Rootpac-R	64 a	570 ab	210 b	148-259
FXA	62 a	558 ab	202	128-301
Titan SG1*	66	609	196	192-200
Hansen 536	65 a	624 bc	182 bc	152-242
Viking	61 a	511 a	177 bc	139-220
Lovell	63 a	673 c	138 cd	102-159
Krymsk 86	63 a	544 ab	83 d	56-98

*Titan SG1 has only 2 replicates in the trial, not 6 as the other rootstocks.