Field Evaluation of Almond Rootstocks

Roger Duncan, UCCE Stanislaus County; Joe Connell, UCCE Butte County; Carolyn DeBuse, UCCE Yolo & Solano Counties; David Doll, Merced County

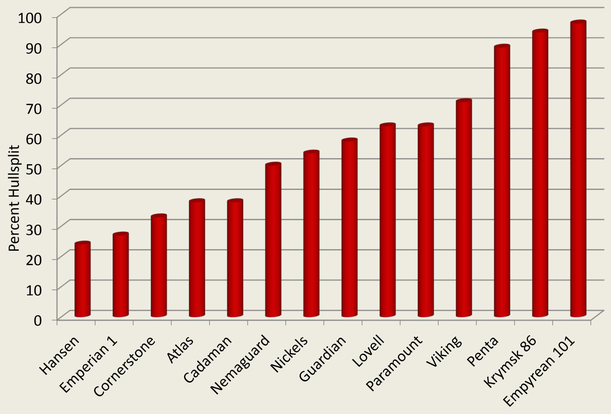
Field Evaluation of Almond Rootstocks for Stanislaus County – Roger Duncan, UCCE Stanislaus County

Trial #1: Field Evaluation of Sixteen Rootstocks in an Unfumigated, Sandy Loam Replant Location

Trial specifics:

- Planted January, 2003
- 2nd generation orchard following nemaguard
- No pre-plant fumigation, fallowed one year
- Hanford sandy loam, pH ~ 6.8
- Flood irrigated with high quality district water

The Influence of Rootstock on Hull Split Nonpareil. August 12, 2011



Yield (kernel pounds per acre) of Nonpareil & Carmel in 2010 (8th Leaf) & Cumulatively (4th – 8th Leaf).

	Nonpareil		Carmel	
	2010 (8th leaf)	Cumulative (4th – 8th leaf)	2010 (8th leaf)	Cumulative (4th – 8th leaf)
Paramount	--	--	3600 a	17,075
Nickels	3204 a	14,719	3529 a	18,744
Hansen 536	3139 a	15,113	3549 a	17,415
Cornerstone	2907 a	14,460	--	--
Empyrean #1	2668 ab	14,194	3405*	16,914*
Atlas	2599 b	12,428	3111 ab	16,140
Avimag	2328 bc	12,059	3085 ab	14,786
Viking	2235 bc	11,447	2569 b	13,354
Guardian	2143 bc	11,273	2398 b	12,391
Lovell	2103 bc	10,897	2455 b	11,486
Nemaguard	1946 c	10,884	2614 b	11,884
Krymsk 86	1416*	7,186*	--	--
Empyrean 101	1357 d	6,028	--	--
Empyrean 2	965*	5,182*	1268*	--
Julior	--	--	924*	--

*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.

General Conclusions After Eight Years

- In general, the peach x almond hybrid rootstocks are the most vigorous and plum rootstocks are the smallest while peach rootstocks are of intermediate size.
- Yield is directly related to tree size; the bigger the tree, the higher the yield.
- The exception: Atlas has consistently outyielded Nemaguard, although the trees are of similar size.
- Smaller trees could be planted closer to increase yield, but it is doubtful that the plum rootstocks would ever produce yields similar to peach x almond hybrids at any spacing in this soil.
- P/A Hybrid rootstocks may perform better than Nemaguard in replant situations as long as ring nematode is not a problem.
- Hull split, and thus harvest, is delayed in the vigorous rootstocks and earlier in the relatively weaker plum stocks

Trial #2: Evaluation of plum & plum hybrid rootstocks on flood-irrigated, sandy soil infested with oak root fungus

Summary of Yield and Root Sucker Numbers on 5th Leaf Trees

	Yield (lb/acre)		Suckers per tree
	Butte	Padre	
Nemaguard	3294 a	2658 ab	0
Viking	2581 ab	3023 a	0
Krymsk 86	2769 ab	2610 ab	0.1
M-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
M 26-24	1580 c	1646 bc	5.8
Tetra	1733 bc	1334 c	0.4

General Conclusions After Five Years

- Nemaguard & Viking are the largest trees.
- Krymsk 86, a peach x plum hybrid, is only slightly smaller than nemaguard with very little suckering.
- Marianna 40 is larger than Marianna 26-24, has higher yields and has no suckers.
- Tetra and Hiawatha are too small and have too many suckers
- No symptoms of oak root fungus have shown as of yet in this trial.

Exploring Alternative Rootstocks in Butte Co.

Cooperators: *Joe Connell, UC Farm Advisor, Butte Co., Almont Orchards, Brouwer Orchards, Sam Lewis & Son Orchards, M&T Chico Ranch*

Objective:

Evaluate compatibility and field performance of alternative rootstocks for tolerance to oak root fungus, to high pH heavy clay soil, or to a high rainfall environment.

Methods:

- Evaluating compatibility and tolerance to oak root fungus: Nonpareil on 'Empyrean 101' is compared to nearby 'Marianna 2624' rooted trees. Nine Nonpareil on 'Krymsk 86' were planted in spots in 2010.
- 'Ishtara', 'Lovell', 'Marianna 2624', and 'Advantage®' rootstocks planted on high pH heavy clay soil are evaluated for variety and rootstock effects on tree size.
- Compare tree size, anchorage and survival on 'Krymsk 86', 'Lovell', and 'Ishtara', fumigated and non-fumigated.
- Six Rootstocks planted March 2010 compare Nonpareil on 'Lovell', 'Atlas', 'Empyrean 1', 'Rootpac-R', 'Krymsk 86', and 'Nickels'.

Results & Discussion:

Vigor on 'Empyrean 101' vs. 'Marianna 2624'

- 'Nonpareil' trees on 'Empyrean 101' rootstock are similar in size and vigor compared to nearby trees on 'Marianna 2624'. No mortality to oak root fungus through 8th leaf.
- Anchorage is poor with four of seven trees leaning. No trees on 'Marianna 2624' are staked or leaning.

Variety & Rootstock Effects on Heavy Soil

- On heavy soil, the 'Ishtara' rootstock is competitive with 'Lovell' in terms of tree size and it produces more vigorous trees than those on 'Marianna 2624' (table 1).
- Anchorage is a problem for 'Ishtara' since 3 out of 30 trees were lost in high winds. No 'Lovell' or 'Marianna 2624' rooted trees were 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

'Krymsk 86', 'Lovell', and 'Ishtara' Rootstocks with and without fumigation

- 47% 'Ishtara' trees leaning, 8% of 'Lovell', but no 'Krymsk 86' leaning. More band canker on 'Lovell' rooted trees (table 2).
- 'Krymsk 86' has largest trunk circ., 'Lovell' benefited most from fumigation (table 3).

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

Rootstock / Treatment	Of Trees Remaining % Leaning	Of Trees Remaining % with Band Canker	Of Original # Trees % 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 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

Six Rootstocks Trial - Planted 2010

- Four of six rootstocks established well with no tree loss. 'Atlas' 10% and 'Nickels' 16% mortality.
- After two growing seasons trees on 'Empyrean 1' are largest and those on 'Krymsk 86' are smallest in circumference (table 4).

Table 4. Trunk circumference and tree loss at planting.

Rootstock	Trunk Circumference (cm) Fall 2010	Trunk Circumference (cm) Fall 2011	% Trees Triple Staked	% Loss 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

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

Project Leader: Carolyn DeBuse, UCCE Farm Advisor, Solano & Yolo Counties

Background:
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 drought tolerant and tolerate shallower soils then 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 and 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, Flordaguard x alnem hybrid (FXA), Krymsk 86, Brights-5, Rootpac-R, and Viking. This trial is an opportunity to explore 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.

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

Methods
The trial is located in Yolo County north of Cache Creek . Nonpareil almond nursery grafted trees on eight different rootstocks (Lovell, Hansen, Nickels, Flordaguard x alnem hybrid (FXA), Krymsk 86, Brights-5, Rootpac-R, and Viking) were planted on February 9, 2011. All trees were planted bareroot except Brights-5 which was potted. The soil is classified as Marvin silty clay loam with a Storie Index (CA) of 2.

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. Twenty trees of Titan SG1 (potted) were planted on April 22, 2011 within the same orchard but not in the replicated 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 randomly collected at 12 and 24 inch depths and bulked by block and analyzed for chemical composition and nematodes.

Planting February 9, 2011

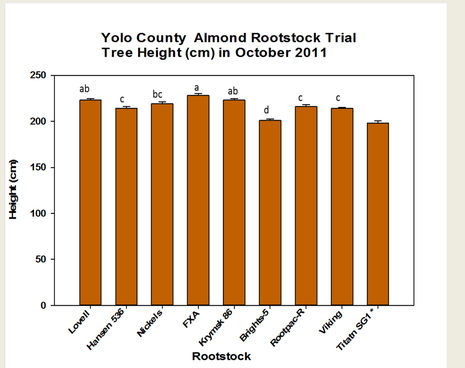
Rootstock Trial November 14, 2011

Results:
There were no tree losses the first year of the trial and all trees grew well. The average measurements are shown in the means table (Table 1) and Figures 1 & 2. There were significant differences between rootstocks for both the diameter and the height. Lovell had a significantly the 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.

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.

Table 1. Means Table for Solano Rootstock trial

	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)	223 (1.79)
Hansen 536	9.10 (0.25)	38.15 (0.40)	214 (1.97)
Nickels	14.09 (0.21)	40.50 (0.52)	219 (2.23)
FXA	13.63 (0.25)	39.51 (0.47)	228 (2.32)
Krymsk 86	13.95 (0.18)	37.82 (0.39)	223 (1.67)
Brights-5	8.36 (0.19)	35.59 (0.32)	201 (1.60)
Rootpac-R	13.87 (0.31)	39.74 (0.36)	216 (2.11)
Viking	15.26 (0.28)	39.75 (0.51)	214 (1.24)
Titan SG1	na	29.77 (0.46)	198 (2.47)



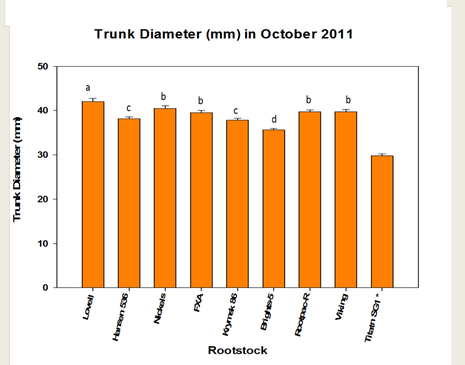


Figure 1 &2 show the trunk diameter (mm)at 18 inches and the height (cm) measured in October 2011. Letters show significant differences between the rootstocks that have different letters grouped by the Duncan test. Titan SG1 is not in the replicated trial and the measurements are considered observational.

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

David Doll, Farm Advisor, Merced County

Cooperating personnel: Glen Arnold, Arnold Farms; Larry Burrows, and Andrew Ray

Introduction: This replicated trial was established in January of 2011 in Winton, CA in Atwater Sand. It will compare the performance of Nonpareil on 14 rootstocks, and the performance of Fritz and Monterrey on seven rootstocks. 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 back-hoed, and the row-strips were fumigated with Telone-II at 33 gallons per acre. Spacing is 22'x18' and trees are irrigated using double line drip.

Rootstocks in this trial include:

Rootstocks planted on Nonpareil, Fritz, and Monterey	Rootstocks planted on Nonpareil, only
Nemaguard	Rootpac(R)-R
Hansen	TemproPac
BH#5	Krymsk-86
Viking	Cornerstone*
Atlas	Cadamen*
Empyrean-1	BB#106
Red Titan III	Floridaguard x Alnem (USDA)

*All trees were planted in late January, 2011 with the exception of Cadamen and Cornerstone. These potted trees were planted in April, 2011.

Table 1: Water analysis taken from the well supplying the trial.

	pH	EC (dS/m)	SAR	Ca (meq/L)	Mg (meq/L)	Na (meq/L)	Cl (meq/L)	B (mg/L)	HCO3 (meq/L)	CO3 (meq/L)	NO3-N (mg/L)
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

Objectives: Rootstocks will be compared 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 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.

Methods: Soil mapping was done using Veris Electrical Conductivity Mapping (Strategic Farming). Zones of soil differences were identified (Figure 1), analyzed (Table 1), and used to help block the trial. Initial and final growth measurements were taken. Light interception was carried out on 3 trees within blocks 1 -3 by using tarps placed on the ground at mid-day during July with area of shade measured. Stem water potential (SWP) was collected from 3 trees in blocks 1-3 using standard procedure. The same trees within each block were measured 4 times, for a total of 12 days of SWP measurements. Water samples were collected twice within the growing season to determine water quality. Nematode samples were collected in October, 2011 and are being analyzed.

Table 2: Pre-plant soil analysis from the identified zones within the field.

	Soil Classification	Organic Matter %	P - Weak Bray PPM	Potassium PPM	Magnesium PPM	Calcium PPM	Sodium PPM	pH	CEC meq/100 g	Base Saturation % K	Mg	Ca	H	Na
Block 1	Sandy Loam	0.7	16	68	264	1172	85	7	8.6	2	25.4	68.3	0	4.3
Block 2	Sandy Loam	0.5	36	63	141	668	39	6.6	5.1	3.1	22.6	64.9	6	3.3
Block 3	Loamy Sand	0.4	55	56	73	366	16	6.7	2.8	5.2	21.8	66	4.5	2.6
Block 4	Loamy Sand	0.4	72	52	62	290	25	6	2.6	5.2	19.7	55.9	15	4.2
Block 5	Loamy Sand	0.5	33	58	81	377	25	6.5	3	4.9	62.1	62.1	7.5	3.6
Block 6	Loamy Sand	0.7	82	64	207	845	82	6.6	6.8	2.4	24.8	61.5	6	5.2

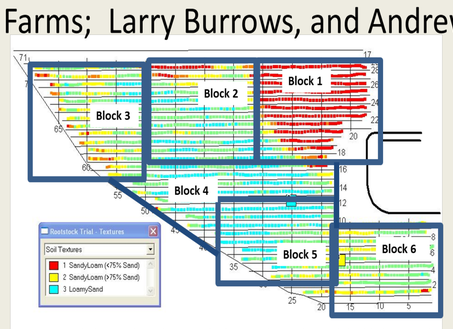


Figure 1: Soil electrical conductivity (EC) map of test plot with highlighted trial blocks. Red areas indicate heavier soil, while blue indicates lighter, coarser soil. EC mapping provides the ability to distinguish soil variations that are not detectable from viewing soil surveys. Differences in EC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

Table 3: Stem Water Potential measured at mid-day for 14 different almond rootstocks.

Rootstock Nonpareil Scion	SWP off Baseline (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

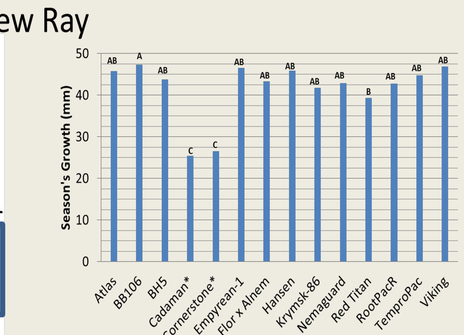


Figure 2: 2011 season's change in caliper of nonpareil scion grafted to 14 different rootstocks. Statistical groupings using mean comparison indicates significance at p<0.05. * indicates a potted tree planted in mid-April.

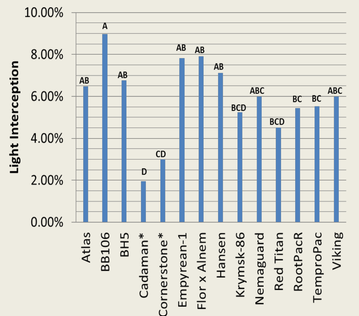


Figure 3: Mid-day light interception of nonpareil scions grafted to 14 different rootstocks. Statistical groupings using mean comparison indicates significance at p<0.05. * indicates a potted tree planted in mid-April.

Results:
- Water and soil quality was suitable for almond production (table 1 and 2);
- Soil variations within field (figure 1) indicated the need to block by soil type;
- Overall, high vigor was observed within the trial, most likely due to presence of nitrate-nitrogen within the irrigation water;
- Growth of the rootstocks was similar for all rootstocks planted bare-root in January, trees planted in April were smaller (figures 2 and 3);
- BB106 had the largest trunk diameter and mid-day light interception (figures 2 and 3);
- All first leaf trees had similar SWP. Krymsk-86 and RootpacR averaged the lowest SWP (most stressed) over the course of the season. Both of these rootstock have plum parentage (table 3).

Acknowledgements: Thanks to Bright's Nursery, Burchell Nursery, Dave Wilson Nursery, and The Nursery Company for donation of trees. Thanks to Strategic Farming, Inc. for soil electrical conductivity mapping.