Field Evaluation of Almond Rootstocks

Project No.: **12-HORT4-Duncan**

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

A. Field Evaluation of Plum & Plum Hybrid Rootstocks for Tolerance to *Armillaria* spp. in a Flood-Irrigated, Sandy Loam, Replant Location. Roger Duncan, Farm Advisor; UCCE - Stanislaus County

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

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

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

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

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

Project Leader: Roger Duncan, UCCE - Stanislaus County

Interpretive Summary:

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.

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.

So far, trees on Viking have the largest trunk circumference while trees on Tetra, Hiawatha and Empyrean 2 are the smallest (**Table 1**). 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.

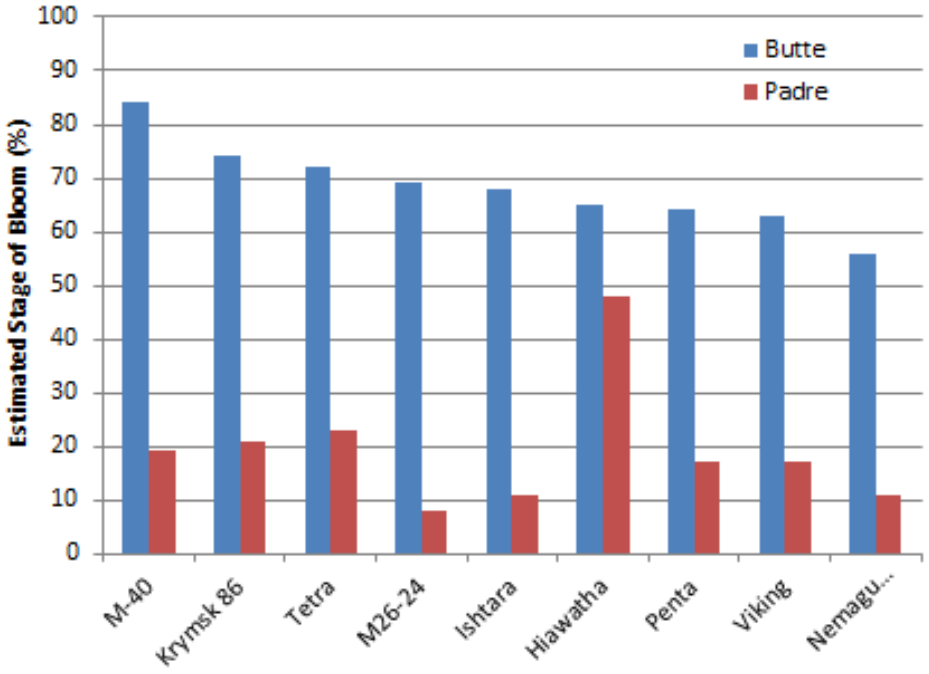
For the first time, signs of Armillaria have been observed in this trial. One tree on Tetra had gumming present at the soil line and Armillaria fruiting bodies developed during the winter of 2012-13. Excavation at the crown revealed Armillaria mycelium has colonized the crown of this one tree. To date, the tree has survived and has shown no obvious signs of decline.

Rootstock had a small and inconsistent effect on bloom earliness in 2012 (**Figure 1**). In general, Butte trees on Marianna 40 bloomed earliest and nemaguard last. Padre trees all bloomed at about the same time with the exception of those on Hiawatha which bloomed significantly earlier than all other rootstocks.

Table 1. Trunk Circumference (cm) of Nine Almond Rootstocks Field Tested for Tolerance to *Armillaria mellea*. April 2013 (7th leaf)

	Butte	Padre
Viking	77.3 a	78.2 a
Nemaguard	73.8 ab	73.4 ab
Krymsk 86	72.5 ab	73.3 ab
Marianna 40	69.8 bc	69.8 bc
Ishtara	65.6 cd	67.3 cd
Marianna 2624	62.6 de	69.3 bc
Tetra	57.8 ef	62.8 d
Penta	56.5 f	62.4 d
Hiawatha	55.3 f	64.7 cd

Fig. 1. Effect of Rootstock on Bloom Earliness
February 24, 2012



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

Project Leader: Roger Duncan; UCCE - Stanislaus County
Project Cooperator: Brent Holtz, UCCE - San Joaquin County

Problem and its Significance:

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.

Materials and Methods:

In this trial, the performance of sixteen rootstocks is 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 increases the likelihood of Verticillium wilt disease. 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:

1.	Lovell	*P. persica*
2.	Nemaguard	*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* × *P. persica*)
13.	Viking	peach x plum x almond x apricot
14.	Atlas	peach x almond x plum x apricot
15.	Krymsk 86	*P. cerasifera* x *P. persica*
16.	Rootpac R	*P. dulcis* x plum

During the development years of the orchard, tree growth will continue to be monitored and the chemical properties of the soil and water will be recorded. When trees reach bearing age, yields will be recorded by using bottom dump nut buggies equipped with livestock scales built into the axels and tongue. Subsamples will be collected to determine kernel size and to calculate yield. Trees will be monitored for signs of disease (Phytophthora, crown gall, Verticillium, etc.). Leaves will occasionally be sampled and tested for salts, including sodium, chloride and boron. Rootstock influences on bloom-time, harvest maturity (hull split date), nut quality and other parameters of interest will be recorded.

Interpretive Summary:

Tree Growth. In general, trees grew well during the first year. Three out of the four largest rootstocks were peach x almond hybrids (PAC9908-02, Hansen and BB 106) (**Table 2**). Empyrean 1, a peach x wild peach hybrid, was also one of the largest rootstocks. Paramount (aka GF-677), was the smallest peach x almond hybrid in the trial other than Brights 5 which was uncharacteristically small because it was planted as a potted tree. PAC9908-02, Hansen, Empyrean 1, BB 106, F x A, Rootpac R, HM2 and

Paramount all had larger trunk caliper than the standard nemaguard ($P \geq 0.05$). Brights 5, Cadaman and HBOK 50 were smaller than most other rootstocks but these were potted trees and were therefore younger and smaller than the bareroot trees at planting time. Krymsk 86 is the smallest rootstock in the trial that was planted as a bareroot tree ($P \geq 0.05$).

Table 2. Trunk Caliper of Sixteen Rootstocks After One Year of Growth

	Trunk Circumference (cm)
PAC9908-02	17.7 a
Hansen	17.2 ab
Empyrean 1	16.9 ab
BB 106	16.9 abc
F x A	16.6 bcd
Rootpac R	16.6 bcd
HM2	16.5 bcd
Paramount	16.1 cde
Viking	15.8 def
Atlas	15.6 efg
Lovell	15.3 efg
Nemaguard	15.1 fg
Brights 5*	14.9 g
Krymsk 86	14.0 h
Cadaman*	13.4 hi
HBOK 50*	12.8 i

*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 (**Table 3**). Samples were collected and sent to Dr. Lynn Epstein, UC Davis plant pathologist, for confirmation. On June 14, 2013, each tree was examined for signs of Verticillium wilt and the percentage of affected canopy was estimated for each.

Half of all trees on Lovell expressed some level of Verticillium wilt. This was the highest incidence of disease for all rootstocks in the trial ($P>0.05$). Paramount and Cadaman also had a high incidence of disease symptoms (30.0% and 25.5%, respectively), significantly more than nemaguard. Empyrean 1, Hansen and nemaguard showed moderate incidence of symptoms (13.3%, 13.3% and 10.0%, respectively). No signs of Verticillium wilt were observed on PAC9908-02, Viking, Atlas, Brights 5 or BB 106. Trees will be examined again in 2014 for more signs of Verticillium wilt.

Table 3. Incidence and Severity of Verticillium Wilt Symptoms Expressed in Nonpareil Almonds Grown on Various Rootstocks. June 2013

	Incidence	Severity
Lovell	50.0 a	7.4 a
Paramount	30.0 b	5.9 ab
Cadaman	25.5 bc	4.3 abc
Empyrean 1	13.3 bcd	2.7 bc
Hansen	13.3 bcd	1.9 c
Nemaguard	10.0 cd	1.2 c
F x A	3.3 d	0.8 c
HBOK 50	3.3 d	1.2 c
HM2	3.3 d	0.7 c
Rootpac R	0.7 d	0.7 c
Krymsk 86	0.3 d	0.03 c
PAC9908-02	0 d	0 c
Viking	0 d	0 c
Atlas	0 d	0 c
Brights 5	0 d	0 c
BB 106	0 d	0 c

C. Exploring Alternative Rootstocks in Butte County

Project Leader: J.H. Connell, Farm Advisor, UCCE - 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:

A) 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 commercial orchards in spring 2010 and ten trees were similarly planted in 2012.

B) 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 was 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 was noted.

C) 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. This trial will be observed periodically (not every year) to characterize tree size differences, tree anchorage, and mortality.

D) Again, working with Brouwer Orchards in Durham and Fowler Nursery, a new rootstock trial was planted March 15, 2010 following the removal of a previous 'Lovell' peach rooted orchard containing some plum rooted replants. This replicated randomized trial evaluates 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. Yield was measured in 2012 (3rd leaf). Mortality and anchorage will be noted as opportunities arise.

Results and Discussion:

A) Nonpareil' scions on the 'Empyrean 101' rootstock are similar in size and vigor to nearby trees on 'Marianna 2624' but four out of seven 'Empyrean 101' rooted trees are leaning and poorly anchored compared to trees on 'Marianna 2624'. Conclusions: 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 succumbed to *Armillaria mellea*.

All nine 'Nonpareil' trees on 'Krymsk 86' planted in spring 2010 in three different oak root fungus spots have established and grown well. In spring 2013 (4th leaf), all nine trees continue to be healthy while a 'Lovell' rooted replant of similar age in one of the fungus spots had died. Ten 'Nonpareil' trees on 'Sam 1', another rootstock being screened for potential *Armillaria* resistance, were planted in an oak root fungus affected orchard in 2012. All trees established well and have so far remained healthy.

B) 'Ishtara' is competitive with 'Lovell' in terms of tree size, and, trees are more vigorous than trees on 'Marianna 2624' (data presented in 2012 annual report). However, 'Ishtara' has been killed by *Armillaria mellea* in other fields. After six growing seasons, 3 out of 30 trees were lost in high winds in 2008. No additional trees have been lost since then but there were no tree losses on 'Lovell' or 'Marianna 2624'. Conclusions: poor anchorage has made this rootstock unacceptable for almonds and it has no other benefits.

C) Data on leaning, diseased, missing trees and on trunk circumference was reported in the 2012 annual report resulting from observations in 2011. 'Krymsk 86' trunk circumference was largest at that time while 'Lovell' benefited most from fumigation. After eight years, 47 percent of the 'Ishtara' trees and 8 percent of the 'Lovell' rooted trees were leaning. There were no leaning trees on the 'Krymsk 86'rootstock. Both 'Ishtara' and the 'Krymsk 86' rootstocks had 5 percent of the trees missing while 'Lovell' rootstock had 10 percent missing.

D) In this "Six Rootstocks" trial, 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). After the third growing season, trees on the 'Empyrean 1' rootstock were largest in circumference and those growing on 'Krymsk 86' were the smallest (**Figure 1**).

At the first harvest of trees in their third growing season, yield was greatest in trees on 'Atlas' and 'Krymsk 86' rootstocks. 'Empyrean 1', 'Lovell', and 'Nickels' rooted trees had the lightest yield while 'Rootpac-R' was intermediate (**Table 1**).

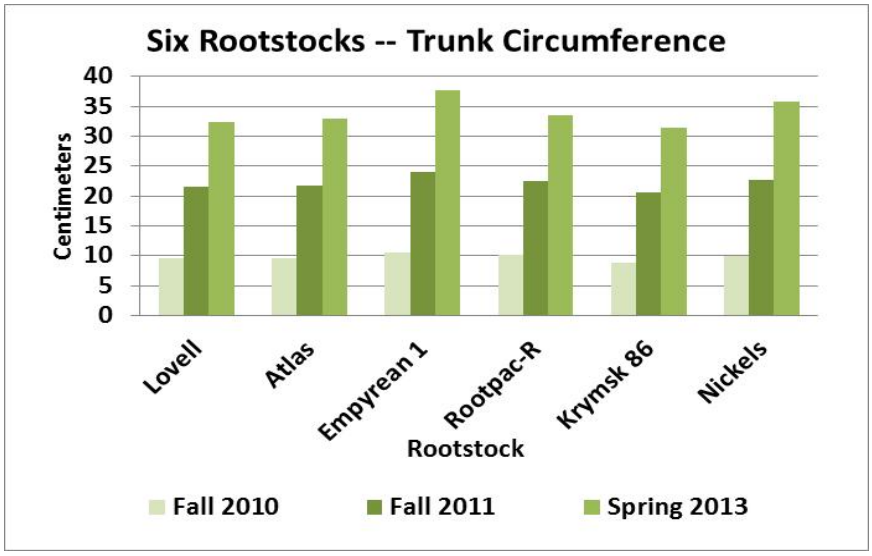


Figure 1. Trunk circumference of trees on six rootstocks following each of the first three growing seasons.

Table 1. 'Nonpareil' yield per tree on six rootstocks at the first harvest in the third growing season.

Six Rootstocks -- 2012 Third Leaf Yield*

Rootstock	Lbs. kernel per tree	
Lovell	0.65	b
Atlas	0.90	a
Empyrean 1	0.61	b
Rootpac-R	0.79	ab
Krymsk 86	0.93	a
Nickels Hybrid	0.71	b

* 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.

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

Project Leader: David Doll, Farm Advisor, UCCE - Merced County
Project Cooperators: Glen Arnold, Arnold Farms; Andrew Ray, UCCE - Merced Technicians

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 and second season of growth. 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 1,236 SWP measurements for each rootstock. Water samples were collected twice within the growing season to determine water quality. Nematode samples were collected in October, 2012. Observations of bloom percentage as influenced by variety and rootstock were taken on March 4th, 2013.

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 varied by rootstock across the three varieties. Within the trees grafted to 'Nonpareil,' 'Atlas,' 'BB106,' 'Empyrean-1,' 'FloridaguardxAlnem,' 'Hansen,' TemproPac,' and 'Viking' were the largest (**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. Within 'Fritz,' 'BH5' and 'Red Titan' were the least vigorous rootstocks (**Table 5**). Within 'Monterey,' 'Empyrean-1,' 'Atlas,' Hansen,' Nemagurd,' and 'Viking' were the largest (**Table 6**).

In 2013, rootstock did not influence progression of bloom (data not shown). Bloom was later than normal, resulting in a compact bloom period. All varieties and rootstocks bloomed similarly with good overlap.

Generally second leaf trees had similar SWP, but differences were found. 'BB106,' 'Cadaman,' Cornerstone,' 'Hansen.' Krymsk-86,' 'Red Titian,' and 'RootPacR' had the lowest SWP (most stressed) over the course of the season (**Table 7**). The increase in stress did not appear to affect the overall growth of 'BB106' and 'Hansen.' It is unknown if tree parentage influences SWP, but both 'Krysmk-86' and 'RootPacR' are of plum parentage.

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 Monterey	Rootstocks planted on Nonpareil, Only
Nemaguard	RootPac (R)
Hansen 536	TemprPac
BH5	Krymsk-86
Viking	Cornerstone*
Atlas	Cadamen*
Empyrean-1	BB#106
Red Titan III	FloridaguardxAlnem (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 1	Sandy Loam	0.7	16	68	264	1172	85	7	8.6	2	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	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	2.6	5.2	19.7	55.9	15	4.2
Block	Loamy Sand	0.5	33	58	81	377	25	6.5	3	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	5.2

Table 3: Analysis of well water from the trial location. Samples were collected in July[1] and October[2], 2011 and sent to UC Davis's Analytical Laboratory for analysis.

	pH	EC	SAR	Ca	Mg	Na	Cl	B	HCO3	CO3	NO3-N
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-	7.90	0.52	0.8	2.44	1.47	1.18	0.42	0.03	2.1	<0.1	17.2

Table 4: 2011, 2012, and total change in trunk caliper of 'Nonpareil' scion grafted to 14 different rootstocks. Groupings of the same letter indicates significance at p<0.05. * indicates a potted tree planted in mid-April.

Rootstock cv 'Nonpareil'	2011	2012	Total
Atlas	45.8 AB	91.9 ABC	137.8 ABCDE
BB106	47.3 A	93.8 AB	141.0 ABC
BH5	43.7 ABC	90.15 ABC	133.9 CDE
Cadaman *	22.7 C	64.2 E	86.9 H
Cornerstone*	26.5 C	71.7 DE	98.2 G
Empyrean-1	46.5 A	101.8 A	148.33 A
Floridaguard x Alnem	42.6 AB	98.3 AB	140.9 ABCD
Hansen	45.7 AB	99.6 AB	145.36 AB
Krymsk-86	41.7 AB	88.1 BC	129.81 DE
Nemaguard	42.9 AB	93.0 ABC	135.9 BCDE
Red Titan III	36.5 B	80.8 CD	117.4 F
RootPacR	41.5 AB	88.1 BC	129.6 E
TemproPacR	44.3 AB	94.2 AB	138.57 ABCDE
Viking	46.9 A	93.5 AB	140.4 ABCDE

* indicates a potted tree planted in mid-April.

Table 5: 2011, 2012, and total change in trunk caliper of 'Fritz' scion grafted to 7 different rootstocks. Groupings of the same letter indicates significance at p<0.05. * indicates a potted tree planted in mid-January

Rootstock cv 'Fritz'	2011	2012	Total
Atlas	45.5	101.2 A	141.1 AB
BH5*	36.5	81.4 B	117.9 C
Empyrean-1	42.2	94.22 AB	136.4 AB
Hansen	44.2	96.93 AB	141.1 AB
Nemaguard	43.9	89.6 AB	133.6 AB
Red Titan III	41.5	84.7 B	126.2 BC
Viking	45.1	95.6 AB	146.9 A

Table 6: 2011, 2012, and total change in trunk caliper of 'Monterey' scion grafted to 7 different rootstocks. Groupings of the same letter indicates significance at p<0.05. * indicates a potted tree planted in mid-January

Rootstock cv 'Monterey'	2011	2012	Total
Atlas	47.1	97.2 ABC	144.3 ABC
BH5*	39.3	87.2 C	126.5 C
Empyrean-1	49.6	105.5 A	155.1 A
Hansen	44.8	98.8 ABC	143.6 ABC
Nemaguard	43.9	91.2 BC	135.1 ABC
Red Titan III	42.6	88.6 C	131.3 BC
Viking	48.8	101.1 AB	149.9 ABC

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	2011 SWP off Baseline (bars)	2012 SWP off Baseline (bars)
Atlas	-1.49 AB	-0.98 ABCD
BB106	-1.86 AB	-1.48 CDE
BH5	-1.94 AB	-1.10 ABCD
Cadaman	-2.2 AB	-1.59 DE
Cornerstone	-2.07 AB	-1.30 BCDE
Empyrean-1	-2.06 AB	-0.43 A
Flor x Alnem	-1.17 A	-0.96 ABCD
Hansen	-1.57 AB	-1.34 BCDE
Krymsk-86	-2.54 B	-1.20 BCDE
Nemaguard	-1.62 AB	-0.86 ABCD
Red Titan	-2.19 AB	-1.60 DE
RootPacR	-2.54 B	-1.76 E
TemproPac	-2.04 AB	-0.79 ABC
Viking	-1.52 AB	-0.67 AB

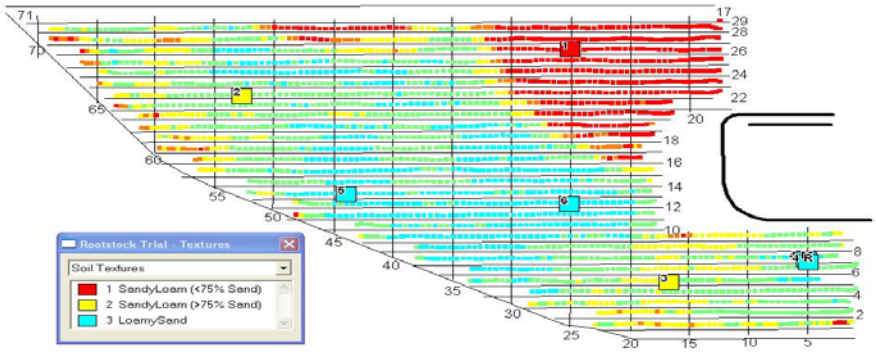


Figure 1: Soil electrical conductivity of the rootstock plot. Red areas indicate heavier soil, while blue indicates coarser soil. EC mapping provides the ability to distinguish soil variations that are not detectable from viewing soil surveys. Differences in EC indicate different water and nutrient holding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

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

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The objective of this study is to evaluate plant growth and boron uptake of Nonpareil almond variety 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 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. In 2012, leaf nutrient analysis was done in July by collecting and bulking the leaves from the 5 trees in each plot. Samples were analyzed by UC Lab. Tree circumference was measured in October.

The average trunk circumferences are shown in the **Table 1**. Summary of the leaf nutrient analysis are shown in **Table 2 - 4**. There were significant differences between rootstocks for both circumferences and leaf nutrient levels. Nickels and FXA were the largest trees while Brights 5 and Krymsk 86 were the smallest trees. Titan SG1 was the smallest but this still may be due to planting time in late spring 2011.

Averaged nutrient levels in the leaves were found to be significantly different between rootstocks. Boron levels were significantly higher in Lovell and Rootpac-R than in Nickels, FXA, and Viking. The other rootstocks were not significantly different from the highest or the lowest. There were significant differences between the level of macro and micro nutrients between the rootstocks. See **Tables 2** and **3** and the letters indicating significant differences using Duncan's multiple range test.

Rootstock suckers were noted to be growing on 76% of Rootpack-R trees and 13% of the Krymsk 86 trees.

Table 1. 2012 Average trunk circumference (±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.

Rootstock	Average Circumference	
Lovell	25.5 ± 0.28	c
Hansen 536	26.3 ± 0.22	ab
Nickels	26.7 ± 0.25	a
FXA	26.8 ± 0.29	a
Krymsk 86	24.2 ± 0.17	de
Brights 5	24.0 ± 0.17	e
Rootpac-R	26.0 ± 0.24	bc
Viking	24.7 ± 0.19	d
Titan SG1*	23.1 ± 0.46	

*not in replicated trial

Table 2. 2012 July average boron (ppm) leaf content of Nonpareil almond on grafted 8 different rootstocks. Letters indicate the significant differences between treatment means at the level p≤ 0.05 using Duncan's Multiple Range test.

Rootstock	B ppm (±SE)			
Lovell	68.55	±	1.28	a
Hansen 536	64.40	±	1.62	ab
Nickels	62.43	±	0.87	b
FXA	61.17	±	2.08	b
Krymsk 86	64.98	±	0.85	ab
Brights-5	65.83	±	1.26	ab
Rootpac-R	67.90	±	1.49	a
Viking	61.08	±	0.93	b
Titan SG1*	65.35	±	4.65	

*not in replicated trial

Table 3. 2012 July average macronutrient content (N,P,K) of Nonpareil almond grafted on 8 different rootstocks. Letters indicate the significant differences between treatment means at the level p≤ 0.05 using Duncan's Multiple Range test.

	N % (±SE)				P % (±SE)				K % (±SE)			
Lovell	2.63	±	0.03	c	0.14	±	0.001	d	1.19	±	0.08	c
Hansen 536	2.69	±	0.02	bc	0.15	±	0.003	bc	1.07	±	0.05	c
Nickels	2.67	±	0.02	bc	0.14	±	0.002	c	1.14	±	0.06	c
FXA	2.66	±	0.01	bc	0.15	±	0.002	bc	1.08	±	0.11	c
Krymsk 86	2.77	±	0.01	a	0.15	±	0.001	bc	1.61	±	0.07	a
Brights-5	2.68	±	0.02	bc	0.15	±	0.002	ab	1.08	±	0.02	c
Rootpac-R	2.67	±	0.02	bc	0.15	±	0.001	a	1.47	±	0.03	ab
Viking	2.70	±	0.02	b	0.15	±	0.003	bc	1.28	±	0.09	bc
Titan SG1*	2.73	±	0.02		0.16	±	0.004		1.19	±	0.01	

*not in replicated trial

Table 4. 2012 July average micronutrient levels (S,Ca, Mg, Zn, Mn, Fe, Cu) of Nonpareil almond grafted on 8 different rootstocks. Letters indicate the significant differences between treatment means at the level p≤ 0.05 using Duncan's Multiple Range test.

Rootstock	S ppm (±SE)			Ca % (±SE)			Mg % (±SE)			Zn ppm (±SE)			Mn ppm (±SE)			Fe ppm (±SE)			Cu ppm (±SE)		
Lovell	1505.00	± 20.94	e	2.48	± 0.04	d	1.29	± 0.04	ab	13.97	± 0.38	f	30.23	± 1.19	c	418.17	± 17.77	ab	5.07	± 0.06	e
Hansen 536	1623.33	± 24.18	ab	3.48	± 0.12	a	1.36	± 0.05	a	15.75	± 0.38	de	40.03	± 2.36	a	396.33	± 14.92	ab	5.88	± 0.07	c
Nickels	1598.33	± 8.72	bc	3.19	± 0.05	b	1.23	± 0.04	bc	17.92	± 0.35	c	32.75	± 1.66	bc	407.50	± 18.07	ab	6.10	± 0.04	b
FXA	1546.67	± 14.06	cde	3.30	± 0.07	ab	1.38	± 0.05	a	20.22	± 0.50	b	39.93	± 1.66	a	390.50	± 16.08	ab	6.53	± 0.08	a
Krymsk 86	1673.33	± 10.85	a	2.33	± 0.06	d	0.94	± 0.02	d	16.88	± 0.21	cd	33.72	± 0.74	bc	445.00	± 14.34	a	5.80	± 0.03	c
Brights-5	1568.33	± 11.38	bcd	2.84	± 0.08	c	1.18	± 0.03	c	23.10	± 0.63	a	36.45	± 1.46	ab	420.33	± 14.28	ab	6.25	± 0.05	b
Rootpac-R	1606.67	± 12.29	b	2.34	± 0.03	d	0.93	± 0.02	d	15.63	± 0.24	e	36.40	± 1.33	ab	438.33	± 11.39	ab	5.88	± 0.06	c
Viking	1540.00	± 30.11	de	2.80	± 0.05	c	1.03	± 0.03	d	12.50	± 0.33	g	29.20	± 1.81	c	408.17	± 16.32	ab	5.27	± 0.12	d
Titan SG*	1620.00	± 10.00		2.81	± 0.05		1.11	± 0.09		18.10	± 0.30		30.60	± 4.40		414.00	± 32.00		6.00	± 0.10	