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# Field Evaluation of Almond Rootstocks

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**Project No.:** HORT4

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Gurreet Brar, CSU Fresno;  
Mohammad Yaghmour, UCCE Kern County.

## A. Summary

This project is a compilation of long-term field assessments of over 25 rootstocks for the culture of almonds in California under various irrigation, weather, disease, and soil chemistry & physical conditions. This project encompasses trials conducted in five counties by UC Cooperative Extension Farm Advisors and a CSU Fresno faculty member.

Selecting the appropriate rootstock for specific soil conditions is critically important for the long-term success of an almond orchard. Rootstocks influence the vigor of a tree, anchorage, and date of crop maturity. More importantly, rootstocks can guard against soil-borne pathogens like nematodes, crown gall, Phytophthora, Verticillium wilt and oak root fungus. They can also affect above ground pathogen susceptibility in the case of hull rot or band canker. Rootstocks tolerant to chemical soil challenges such as high pH, sodium, chloride or boron enable growers to successfully farm almonds in marginal soils or where water is of lower quality.

Nemaguard and Lovell, long-time industry standard rootstocks, have some significant flaws. Both often perform poorly in heavy, alkaline soils and are susceptible to Phytophthora, oak root fungus, crown gall, and other diseases. Nemaguard is also susceptible to ring nematode and bacterial canker while Lovell is highly susceptible to rootknot nematode and crown gall. Oftentimes growers should consider alternative rootstocks for a more productive, longer lasting orchard requiring fewer inputs. This project involves several, separate field trials evaluating over 25 rootstocks from various public and private breeding programs around the globe.

## B. Objectives

1. Evaluate sixteen rootstocks irrigated with marginal quality irrigation water in alkaline, heavy soil (Roger Duncan, UCCE Stanislaus County).
2. Continue evaluation of variety compatibility with rootstocks for almond, particularly compatibility with Nonpareil, under upper Sacramento Valley growing conditions (Joe Connell, UCCE Butte County Emeritus).
3. Evaluate alternative rootstocks under high boron, West San Joaquin Valley conditions (Katherine Jarvis-Shean, UCCE Yolo County).
4. Evaluate conventional as well as growth controlling rootstocks for growth, yield, water use efficiency and photosynthetic parameters (Gurreet Brar, CSU Fresno.)
5. Evaluate eleven rootstocks under Kern County growing conditions, especially challenged with periodic high Santa Ana winds (Mohammad Yaghmour, Kern County).

In the past, researchers measured rootstock parameters most relevant to their trial location. In 2019 & 2020, researchers attempted to measure several standardized parameters in each plot, along with evaluations relevant to each individual location. These included:

- Complete leaf analyses of non-fruiting spur leaves (July)
- Hull analysis for boron (at harvest)
- Soil analyses 0-18" & 18-36" deep
- Rootstock effect on hullsplit timing and duration
- Yield and quality assessment
- Trunk circumference
- Trunk angle (measure of anchorage)
- Photosynthetically Active Radiation (PAR)
- Pathogenic nematodes

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

Project leader: Roger Duncan, UCCE Advisor, Stanislaus County  
Grower Cooperator: Lee Del Don

#### **Objective:**

Evaluate 16 almond rootstocks for their performance in an alkaline clay loam soil moderately high in boron and irrigated with water sometimes high in chloride.

#### **Interpretive Summary:**

- The largest trees as measured by trunk circumference at the end of the 9<sup>th</sup> leaf were on Empyrean 1 or the peach x almond hybrids Flordaguard x Alnem, BB 106, Hansen and Hansen x Monegro (Table 4). Paramount (a.k.a. GF 677) and Brights 5 are significantly smaller than the other PxA hybrid rootstocks and are similar in size to trees on Viking, Atlas and Nemaguard. Lovell and Krymsk 86 are the smallest trees in this trial.
- Hansen x Monegro (HM2) has unacceptably poor anchorage. HBOK 50 and Empyrean 1 have questionable anchorage and may have problems in windy areas.
- July leaf analyses indicate that leaf chloride levels are increasing in this trial. Although many rootstocks have had leaf levels well above the critical level for many years, obvious leaf toxicity symptoms are only now beginning to show in some rootstocks. Krymsk 86 and PAC9908-02 have significantly higher leaf chloride than other rootstocks (over 1.1%), although leaf levels in Nemaguard and Lovell are also dangerously high. Most peach x almond hybrid rootstocks and Rootpac R have significantly lower leaf chloride and are below the critical level threshold of 0.3%.
- Lovell, Atlas, Cadaman, and HBOK 50 had the highest hull boron while many rootstocks showed significantly lower hull boron
- The highest yielding rootstocks tend to be the most vigorous. However, many of the larger, highest yielding stocks also had higher yield efficiencies than smaller, lower yielding rootstocks, using trunk circumference as a measure of tree size. Standard rootstocks Lovell, Nemaguard and Krymsk 86 were among the lowest yielding in 2020

and have the lowest cumulative yields in this trial, producing only 40-60% of the crop of the highest yielding rootstocks. Lovell had the lowest yields and the lowest yield efficiency. Brights 5 appears to have significantly higher yield efficiency in this trial due to its high yield on a moderate-sized tree.

### **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 on the east side of the valley with more neutral pH, nematode infested, sandy loam soils, west side soil is typically heavy with higher salt and boron levels and the pH is often 7.5 or higher. The irrigation water is typically high in bicarbonates, boron and chloride. Historically westside growers have planted on Lovell or Nemaguard due to lack of information or experience with alternative rootstocks. Partly because of poor rootstock choice, almond yields on the west side are generally lower than the east side of the North San Joaquin Valley.

### **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. 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. The list of rootstocks and their genetic background is shown below (Table 1).

The rootstock trial is growing in a Zacharias clay loam. Preplant soil samples indicated moderately high soil pH (7.5), high magnesium (555 ppm), high boron (1.7 ppm) and moderate soluble salts (1.3 mmhos / cm). In previous years, the field was irrigated primarily with West Stanislaus Irrigation District water, which is blended with tail water from area fields and water from the San Joaquin River. The water quality can be variable through the season and sometimes high in salts, especially towards the end of summer. During the drought, this orchard was primarily irrigated with well water. The water is treated with sulfuric acid but is still high in sodium, chloride, boron and bicarbonate (Table 2.). After three years of irrigation with well water, soil samples indicated very high total salinity (2.5 – 3.4 dS/m), high sodium (9.4-14.7 meq/l) and very high chloride (11.0 – 17.1 meq/l) (Table 3.). After the drought, the orchard has been irrigated with district water which is of much better quality (Table 2). The most recent soil and water samples indicate the soil chemistry has improved in some ways but still has high pH and salts. Prior to planting the orchard, the field had a long history of melons, tomatoes and other row crops which led to expression of Verticillium wilt disease in the early years of this trial. Preplant and subsequent 8<sup>th</sup> leaf soil samples indicated no detectable rootknot or ring nematodes.

Rootstock	Genetic Background
Lovell	Domestic peach
Nemaguard	Domestic peach
Empyrean 1	Domestic peach x wild peach
Avimag (a.k.a. Cadaman)	Domestic peach x wild peach
HBOK 50	Harrow blood peach x domestic peach
Hansen	Peach x almond
Brights #5	Peach x almond
BB 106	Peach x almond
Paramount (a.k.a. GF 677)	Peach x almond
Flordaguard x Alnem (FxA)	Peach x Israeli bitter almond
PAC9908-02	(peach x almond) x peach
HM2 (Hansen x Monegro)	(almond x peach) x (almond x peach)
Viking	((plum x apricot) x almond) x peach
Atlas	((plum x apricot) x almond) x peach
Krymsk 86	Plum x peach
Rootpac R	Almond x plum

	EC (dS/m)	Na (meq/l)	Adj. SAR	Cl (meq/l)	CO <sub>3</sub> +HCO <sub>3</sub> (meq/l)	B (mg/l)	pH
2015	1.86	9.40	8.80	8.9	2.50	0.84	7.1
2017	0.96	4.13	3.07	3.64	2.16	0.31	7.9
2020	1.42	6.61	3.97	6.06	3.11	0.89	7.5
Critical Levels	< 1.10		< 3.0	< 4.0		0.50	

Sample Depth (in.)	pH	EC (dS/m)	Ca (meq/l)	Mg (meq/l)	Na (meq/l)	Cl (meq/l)	B (mg/l)	ESP (%)
At Planting (2012)								
0-18"	7.3 - 7.8	3.42	7.2	14.7	14.7	17.1	0.6	5.0
18"-36"	7.8	2.49	5.9	12.9	9.4	11.0	0.3	3.2
Current (December 2020)								
0-18"	7.1 - 7.8	0.8-2.3	2.6-8.8	1.7-8.3	4.9-9.6	1.0-5.8	0.4-0.7	3.4
18 - 36"	7.8 - 8.2	1.0-2.1	2.0-5.7	3.0-10.4	4.9-10.8	1.4-4.7	0.4-1.0	4.0
36 - 52"	8.2 - 8.4	1.0-2.4	1.8-4.7	3.5-11.0	4.9-15.5	1.5-5.2	0.4-0.7	4.9
Critical level		1.50				5.0	0.5	5.0

## Results & Discussion:

**Tree Growth.** The largest trees as measured by trunk circumference at the end of the 9<sup>th</sup> leaf were on FxA, BB106, Hansen, HM2 and Empyrean 1 (Table 4). Paramount (a.k.a. GF 677) and Brights 5 are significantly smaller ( $P<0.05$ ) than the other PxA hybrid rootstocks and are more similar in size to trees on nemaguard in this trial. Trees on Lovell and Krymsk 86 are the smallest in this trial.

	2015 Trunk Circumference 4 <sup>th</sup> Leaf (cm) <sup>1</sup>	2017 Trunk Circumference 6 <sup>th</sup> Leaf	2019 Trunk Circumference 8 <sup>th</sup> Leaf	2020 Trunk Circumference 8 <sup>th</sup> Leaf
Flordaguard x Alnem	49.7 abc	60.9 a	67.6 a	73.0 a
BB 106	48.0 bc	57.5 c	65.0 abc	71.4 ab
Hansen	47.9 c	58.3 bc	65.7 ab	70.9 abc
Hansen x Monegro	48.4 bc	58.4 abc	65.6 ab	68.0 abc
Empyrean 1	50.0 ab	59.3 abc	65.9 ab	68.3 abc
PAC9908-02	50.8 a	60.3 ab	63.9 bc	67.5 bc
Rootpac R	49.0 abc	58.1 bc	62.2 c	65.4 bc
Paramount	43.3 ef	51.6 ef	58.1 d	62.6 cd
Brights 5	43.8 de	52.0 def	56.8 de	61.7 d
HBOK 50	45.6 d	54.4 d	58.5 d	61.4 de
Atlas	44.3 de	52.8 de	55.9 de	60.8 de
Viking	44.2 de	51.9 def	56.0 de	60.4 de
Nemaguard	44.6 de	52.7 def	56.3 de	59.0 de
Krymsk 86	41.7 f	48.6 g	55.8 de	56.3 e
Lovell	42.9 ef	50.2 fg	53.4 e	56.1 e

**Anchorage.** Wind can be a problem on the west side of the North San Joaquin Valley, causing young trees to lean excessively. It is therefore important for almond rootstocks to have good anchorage. To quantify tree anchorage, a large protractor was used to measure trunk angles relative to the orchard floor. Trunk leaning of greater than about 15 degrees likely indicates an anchorage problem. Hansen x Monegro (HM2) has unacceptably poor anchorage, with an average trunk angle of 21 degrees in 2017. Two thirds of trees on this rootstock are leaning more than 15 degrees and some have had to be propped with boards or removed. HBOK 50, Empyrean 1 and Lovell may have questionable anchorage in windy areas. All had at least one third of the trees leaning more than 15 degrees.

	2017	2019
Krymsk 86	5 a	9 a
PAC9908-02	5 a	9 a
Viking	6 a	10 a
Hansen	6 a	12 abc
Flordaguard x Alnem	8 ab	11 ab
Nemaguard	8 ab	12 abc
Rootpac R	9 abc	12 abc
Brights 5	9 abc	12 abc
Lovell	9 abc	13 abc
Atlas	10 bcd	13 abc
Paramount	11 bcd	12 abc
BB 106	14 bcd	12 abc
Empyrean 1	15 cde	16 cd
HBOK 50	16 cde	16 bcd
Cadaman	17 de	--
Hansen x Monegro	21 e	18* d

	N (%)	P (%)	K (%)	Sulfur (ppm)	Ca (%)	Mg (%)	Mn (ppm)	Na (%)
Lovell	2.33 bc	0.11 a	1.38 cd	2600 bcd	2.69 g	1.33 cde	72.4 bcd	0.15 bcd
Nemaguard	2.37 abc	0.11 a	1.85 abcd	2570 bcd	2.93 fg	1.31 cde	65.9 cd	0.25 b
Empyrean 1	2.34 abc	0.11 a	1.95 abc	2480 bcd	3.21 def	1.53 ab	63.9 abcd	0.12 cd
Cadaman	2.43 ab	0.12 a	2.44 a	2003 d	3.53 bcd	1.29 de	74.8 abcd	0.04 d
HBOK 50	2.28 c	0.11 a	1.63 bcd	2578 bcd	2.93 fg	1.49 ab	92.7 a	0.06 d
Hansen	2.34 abc	0.12 a	2.22 ab	2080 cd	4.21 a	1.41 abcd	91.5 ab	0.09 d
Brights 5	2.35 abc	0.12 a	2.46 a	2030 d	3.65 bc	1.32 cde	72.3 bcd	0.04 d
BB 106	2.48 a	0.12 a	2.40 a	2500 bcd	3.79 b	1.39 bcd	61.8 d	0.05 d
GF 677	2.38 abc	0.12 a	2.15 ab	2143 cd	3.66 bc	1.21 e	82.3 abc	0.04 d
F x A	2.44 ab	0.12 a	2.48 a	1923 d	3.64 bc	1.32 cde	90.8 ab	0.06 d
PAC9908-02	2.41 abc	0.11 a	1.23 d	3623 a	3.37 cde	1.55 a	80.8 abcd	0.24 b
HM2	2.41 abc	0.11 a	2.14 ab	2625 bcd	3.29 cdef	1.42 abcd	82.9 abc	0.10 d
Viking	2.37 abc	0.11 a	1.90 abcd	2968 ab	3.27 cdef	1.39 bcd	82.2 abc	0.06 d
Atlas	2.43 abc	0.11 a	1.94 abc	2538 bcd	3.12 ef	1.28 de	81.6 abcd	0.22 bc
Krymsk 86	2.47 a	0.11 a	1.39 cd	3208 ab	3.49 bcde	1.46 abc	92.4 a	0.22 bc
Rootpac R	2.40 abc	0.11 a	1.57 bcd	2808 bc	3.23 def	1.29 de	90.8 ab	0.40 a

<sup>1</sup>Measurements followed by the same letters are not significantly different ( $P \leq 0.05$ ).

<sup>2</sup>Zinc values not shown. In-season foliar sprays made analyses inconclusive.

**Rootstock Effect on Leaf Nutrients, Salt and Boron.** With the exception of phosphorus, leaf nutrient levels differed significantly among rootstocks ( $P < 0.05$ ). While differences in most nutrients were statistically significant, they were not agronomically important in many cases because levels were well above recommended levels (Table 6). The most notable differences occurred in leaf levels of potassium, sodium and chloride. All peach x almond hybrids except PAC9908-02 had high levels of potassium ( $> 2.1\%$ ) while PAC9908-02, Lovell and Krymsk 86 were deficient on average ( $< 1.4\%$ ). Although all peach x almond hybrids tended to be higher in calcium, Hansen was significantly higher than all rootstocks. Nemaguard, Lovell and HBOK 50 were the lowest in calcium.

Signs of ion toxicity were very apparent in the trial in 2020. Chloride levels are well above the published critical level (0.3%) for several of the rootstocks. July leaf analyses have indicated that chloride levels are the highest in PAC9908-02 and Krymsk 86 while levels are also very high in Lovell and Nemaguard (Table 7). All peach x almond rootstocks except PAC9908-02 had comparatively low chloride levels, most well below the critical threshold. There are significant differences in the accumulation of boron in hulls among the rootstocks, although all are well below the critical hull boron level of 300 ppm (Table 8). Boron levels were highest in Lovell, Cadaman, Atlas and HBOK 50 in most years. Boron levels were lowest in the peach x almond hybrid rootstocks, Rootpac R and Viking and are now B deficient.

	% Chloride 2015	% Chloride 2016	% Chloride 2017	% Chloride 2020
Krymsk 86	0.65 b	0.77 a	0.89 a	1.21 a
PAC9908-02	0.28 defg	0.45 bc	0.45 d	1.10 a
Nemaguard	0.43 c	0.57 b	0.57 c	0.96 b
Lovell	0.73 a	0.72 a	0.72 b	0.95 b
HBOK 50	0.30 def	0.31 cde	0.31 ef	0.68 c
Atlas	0.37 cd	0.42 c	0.42 de	0.57 cd
Viking	0.25 efgh	0.30 cde	0.30 f	0.55 d
Cadaman	0.32 de	0.38 c	0.38 def	0.54 d
HM2	0.18 h	0.16 e	0.16 g	0.39 e
Empyrean 1	0.32 de	0.33 cd	0.33 ef	0.36 e
F x A	0.20 gh	0.29 cde	0.19 g	0.28 ef
Hansen	0.23 efgh	0.15 e	0.15 g	0.28 ef
BB 106	0.20 gh	0.19 de	0.19 g	0.25 ef
Rootpac R	0.25 efgh	0.17 de	0.17 g	0.22 f
Brights 5	0.22 fgh	0.18 de	0.18 g	0.17 f
Paramount	0.20 gh	0.18 de	0.19 g	0.16 f
<b>Critical Level</b>	<b>0.30%</b>			

Table 8. Hull Boron Levels of Fourth-Leaf Through Seventh-Leaf Nonpareil Almond Trees Grown on Sixteen Rootstocks. September 2015 – 2018				
	ppm Boron 2015	ppm Boron 2016	ppm Boron 2017	ppm Boron 2018
Lovell	180 a	125 a	180 a	125 a
Cadaman	170 ab	107 ab	170 ab	110 ab
Atlas	158 ab	123 a	158 ab	122 a
HBOK 50	156 ab	108 ab	158 ab	114 ab
Nemaguard	153 bc	114 ab	153 bc	110 ab
Krymsk 86	152 bc	100 ab	152 bc	97 b
Empyrean 1	133 cd	89 bc	133 cd	93 bc
Rootpac R	132 cd	93 b	132 cd	93 bc
Hansen	126 de	86 bc	126 de	91 bc
Paramount	120 de	78 bc	120 de	79 c
HM2	116 de	82 bc	116 de	86 bc
Viking	109 e	74 c	109 e	77 c
PAC9908-02	108 e	75 c	108 e	80 c
Brights 5	106 e	76 c	106 e	75 c
F x A	104 e	80 bc	104 e	83 c
BB 106	102 e	76 c	102 e	88 bc
<b>Critical Level</b>	<b>300 ppm</b>			

**Yield.** Rootstock has substantially affected yields in this trial (Table 9). The highest yielding rootstocks have accumulated over 4200 pounds per acre (about 50%) more than the lowest yielding rootstocks through the 7<sup>th</sup> leaf. The highest yielding rootstocks tend to be the most vigorous trees (peach x almond hybrids and Empyrean 1). Industry standards Lovell, Nemaguard and Krymsk 86 are the lowest yielding rootstocks in the trial. Brights 5 has the highest yield efficiency as measured by dividing cumulative yield by tree size (trunk circumference). Although Rootpac R has not performed well in most other UC trials, it looks pretty good here. Perhaps the combination of tolerance to salt and heavy soil make it an appropriate choice for heavy, alkaline soil.

	2020 Yield (9 <sup>th</sup> Leaf)	Cumulative Yield (4 <sup>th</sup> thru 7 <sup>th</sup> & 9 <sup>th</sup> Leaf)	2020 Yield Efficiency*
BB 106	4091 a	16,294	52.3
F x A	3170 bcd	15,446	43.4
Brights 5	3859 ab	15,423	62.5
Hansen	3661 ab	15,016	51.6
HM2	3447 abc	14,808	50.7
Empyrean 1	3096 bcde	14,557	45.3
Rootpac R	2826 cde	13,413	43.2
PAC9908-02	2470 de	13,386	36.6
Atlas	2626 de	13,132	43.2
Paramount (GF 677)	3084 bcde	12,663	49.3
Viking	2791 cde	12,495	46.2
Nemaguard	2791 cde	11,624	47.3
HBOK 50	2326 ef	11,527	37.9
Krymsk 86	2474 de	11,340	43.9
Lovell	1680 f	9,720	29.9

\*Yield efficiency is estimated by dividing 2020 yield by 2020 trunk circumference

**Nematodes.** Nematode populations were analyzed for the 9<sup>th</sup> leaf rootstock trial in clay loam soil and a 17<sup>th</sup>-leaf rootstock trial in an unfumigated sandy loam (see previous rootstock reports, Gemperle Trial). Soil cores were sampled with an Oakfield Sampler down to a 15 inch depth within the rootstozone of the trees in March, 2019. Soil samples were analyzed for pathogenic nematode numbers by Nematodes Inc (Selma, CA) using sieve and centrifugal flotation extraction. No serious pathogenic nematode species were detected in the Westside clay loam soil (Table 10). Ring and Root Lesion nematodes were present in the sandy loam Gemperle trial (Table 11). Viking, Guardian, Empyrean 1 had very low populations of ring nematodes in this trial.

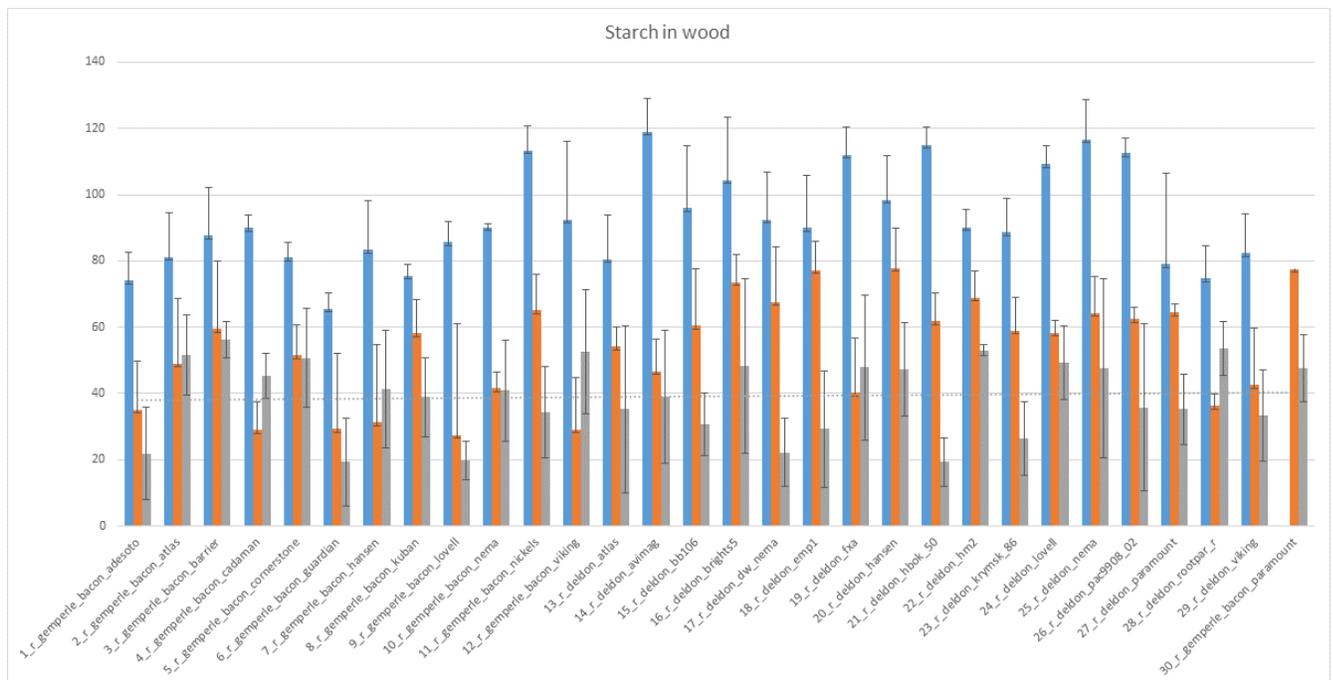
	Ring ( <i>Mesocriconema xenoplax</i> )	Root Lesion ( <i>Pratylenchus vulnus</i> )
Nickels	1438 a	34 a
Cornerstone	1176 a	2 a
Hansen	396 b	37 a
Adesoto	257 b	112 a
Cadaman	156 b	22 a
Nemaguard	137 b	69 a
GF 677	118 b	103 a
Atlas	97 b	35 a
Lovell	19 b	36 a
Krymsk 86	10 b	0 a
Empyrean 1	1 b	13 a
Guardian	0 b	38 a
Viking	0 b	18 a

**Water stress.** Midday stem water potential (SWP) was determined for eight of the 16 rootstocks using a pressure chamber (Soil Moisture Equipment Manufacturing, Inc.) on July 9, 2019 (Table 12). This was just prior to an irrigation and all rootstocks showed excessive water stress. Viking and Rootpac R were significantly more water stressed than the other monitored rootstocks (P<0.05).

Rootstock	SWP (bars)
Viking	-21.9 a
Rootpac R	-21.0 a
Nemaguard	-18.3 b
Atlas	-17.7 b
Brights 5	-17.3 b
Krymsk 86	-16.8 b
Hansen	-16.5 b
Empyrean 1	-16.5 b

**Rootstock effect on carbohydrates.** One-year-old shoots were sampled from trees on each rootstock and delivered to Dr. Zwieniecki’s laboratory at UC Davis for carbohydrate analyses in December and February, 2018 and 2019 and again in 2019-20. In general, the peach rootstocks (Guardian, Lovell, Nemaguard, HBOK 50) and plum / plum cross rootstocks (Adesoto, Krymsk 86) had the lowest pre-bloom wood starch levels (Fig. 1). Peach x almond hybrids and Empyrean 1 had the highest level of starch. Higher carbohydrates may be related to higher vigor and yield. 2019-20 samples still in process.

Figure 1. Starch Storage Levels in One-Year-Old Wood in December 2018 (Blue), January 2019 (Red) and Pre-bloom 2019 (Green). Del Don and Gemperle Rootstock Trials, Stanislaus County.



## **B. Evaluation of Alternative Rootstocks in Butte County**

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**Project Cooperators:** Luke Milliron, Butte-Glenn-Tehama Farm Advisor, Luis Hernandez and German Campos, Deseret Farms of California–Durham, and Fowler Nursery

**Objectives:** Evaluate Nonpareil vigor and compatibility with rootstocks for almond and assess tree field performance.

### **Materials and Methods:**

Working with Brouwer Orchards and Fowler Nursery, a rootstock trial was planted on March 15, 2010 following the removal of a previous ‘Lovell’ peach-rooted orchard containing some plum rooted replants. Deseret Farms of California--Durham subsequently acquired the orchard and research continued. Tree spacing in this orchard is 24 feet across the middles by 16 feet down the tree row giving a tree population of 113 trees per acre. This replicated randomized trial compared 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-R’, ‘Atlas’, ‘Krymsk 86’, and ‘Empyrean 1’ are compared to standard rootstocks ‘Nickels’ and ‘Lovell’.

Tree growth was documented with trunk circumference measurements. Nut size and yield data were collected annually through the tenth growing season. Nut quality was reported following the 2019 harvest. Tree nutrition was characterized with leaf analysis in the seventh, ninth, and tenth growing seasons. Nut maturity measured as the timing and progression of hullsplit was determined in the ninth and tenth growing seasons; as was pre-harvest stem water potential. These data can be found in previous annual reports to the Almond Board.

Soil sampling for nematodes was done in each replicate for all rootstocks on February 14, 2020 and submitted to Nematodes, Inc. in Selma for analysis. Extraction from a 250 cc sample was done by sieving and centrifugal flotation. Results are reported at 100% extraction. Data was processed by an analysis of variance and using Fishers protected LSD procedure for mean separation.

### **Results and Discussion:**

Nematodes have not been a serious a problem in Butte County almond orchards in the past. With high rainfall and mostly loam and clay loam soils, nematodes had minimal impact when ‘Lovell’ peach rootstock was dominant. Now that ‘Krymsk 86’ rootstock predominates in new Butte County orchards the data in Table 1 suggests this situation may continue as long as root-knot nematode is not present. Trees on ‘Krymsk 86’ in other locations have been seriously stunted when root-knot nematode is present.

There were no significant differences in lesion and pin nematode populations found on the six rootstocks in this trial (Table 1). Root-knot nematodes (*Meloidogyne spp.*) were not detected in this orchard and lesion nematodes were found in one of 5 replicates only on the ‘Lovell’ peach rootstock. The ‘Nickels’ peach-almond hybrid rootstock had the lowest population of dagger nematodes while the ‘Empyrean 1’ peach hybrid rootstock had the highest dagger nematode

population. The other rootstocks were intermediate in dagger nematode populations.

Table 1. Rootstock effects on Nematode susceptibility, Durham, CA

Rootstock	Mean Nematode Population / 250cc sample		
	Lesion <i>Pratylenchus vulnus</i>	Dagger <i>Xiphinema americanum</i>	Pin <i>Pratylenchus</i>
'Lovell'	10.4	24.4 abc	192.8
'Krymsk 86'	0	6.0 ab	220.0
'Atlas'	0	29.2 bc	609.2
'Empyrean 1'	0	38.4 c	627.6
'Nickels'	0	2.4 a	435.2
'Rootpac-R'	0 ns	8.4 ab	170.8 ns

Values followed by the same letters are not significantly different at  $P < 0.05$  using Fisher's least significant difference (LSD) procedure; ns indicates there were no significant differences between rootstocks in nematode populations.

This completes my field work in the Durham, California rootstock trial. Although the data mentioned above and in previous annual reports is complete, if extreme environmental conditions result in tree loss in future years, impacts on tree mortality and anchorage related to rootstock will be noted.

I appreciate the financial support of the Almond Board of California without which laboratory analysis would not have been possible. The support of Fowler Nursery in establishing the trial, and of cooperating growers Brouwer Orchards, Deseret Farms of California-Durham, and the orchard managers over the past 10 years, Rex Smith, Sam Richardson, German Campos, and Luis Hernandez, all of whom made this work possible are gratefully acknowledged.

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

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**Project Cooperators and Personnel:** Lampinen Lab, UC Davis; Carolyn DeBuse, USDA

#### Objectives:

To evaluate plant growth, tree crop yield and boron uptake of Nonpareil almond variety on nine different rootstocks in the Sacramento Valley when grown on a marginal soil high in boron.

#### Interpretive Summary:

The trees on Titan SG1, Nickels, FxA and Brights 5 continue to produce higher yields in these high boron conditions than the trees on other rootstocks. Hansen 536, despite also being a peach-almond (P x A) hybrid and showing no significant difference in terms of size, continues

to be lower yielding than other peach-almond hybrids. Trees on Rootpac-R, Krymsk 86 and Lovell produced the lowest yields, in keeping with their smaller tree size. These results are consistent with previous yields – P x A hybrids except Hansen 536 yielding highest; Krymsk 86 and Lovell yielding lowest. Notably, this is the second year that Rootpac-R yields have grouped with Krymsk-86 and Lovell. Viking has consistently been in the middle of the pack, yield-wise.

Certainly the larger size of the P x A hybrids plays a role in their higher yields, but the yield-size efficiency numbers in Table 1 also show that even if planted more closely, trees on non-PxA rootstocks would not catch up to P x A yields on a per-acre basis.

### **Materials and Methods:**

Rootstocks with potential high boron tolerance relative to the commonly planted Lovell peach were identified: Hansen 536, Nickels, FxA, Krymsk 86, Brights-5, Rootpac-R, and Viking. This study assesses potential differences in boron tolerance between these rootstocks. Titan SG1 was added after the initial planting. Data collected from this rootstock is reported but considered observational because it is not replicated.

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. Irrigation water boron concentrations range between 1-3 ppm B.

Nonpareil almond nursery-grafted trees on eight different rootstocks (Lovell, Hansen, Nickels, 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 22' across the row and 18' down the row. 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.

In 2020, the orchard was in its 10<sup>th</sup> leaf. Yield per acre was calculated following harvest of 5-tree replicates by the grower. Hull nutrient assessment was done using samples collected at harvest, with hulls from all 5 trees in each replicate pooled into a single sample. Samples were analyzed for boron by UC Davis Analytical Lab.

### **Results and Discussion:**

Significant differences in average yield per acre were measured between rootstocks in 2020, the eighth harvested crop (Table 1). Trees on peach x almond (PxA) hybrids Titan SG1, Nickels, FxA and Brights 5 produced the highest average yields per acre while Lovell, Rootpac R and Krymsk 86 rooted trees produced the lowest yields. Hansen 536, despite also being a P x A hybrid and showing no significant difference in terms of size, continues to be lower yielding than other P x A hybrids. These results are consistent with previous yields – PxA hybrids except Hansen 536 yielding highest; Krymsk 86 and Lovell yielding lowest. Notably, this is the second year that Rootpac-R yields have grouped with Krymsk 86 and Lovell. Viking has consistently been in the middle of the pack, yield-wise. PxA hybrid yields in 2020 were fairly high for Yolo County, but the scale, data sheets and calculations were repeatedly checked for errors and none were found. Growers should not expect to consistently achieve

these yields under high boron conditions. More than absolute yields, the important take-away from this year is that rootstock ranking by yield is consistent with previous years.

Unlike most plant species, plants in the *Prunus* genus (almond and other stone fruit) accumulate boron in the fruit. *Leaf boron levels are not a good indicator of toxicity in almond.* Instead, boron in the hulls at harvest is used. Boron conditions are considered toxic if hull boron accumulates above 300 ppm. In 2020, hull B was below this toxic threshold in all cases, however levels were significantly (around 60%) higher in Lovell, with means ranging from 148 ppm to 178 ppm in all rootstocks except Lovell, which had 262 ppm B in hull on average (Table 1). This is not surprising given the low yields and poor health of Lovell trees in this trial over the course of the experiment.

Canopy light interception (PAR%) measurements (Table 1) can help decipher whether trees were low yielding because of smaller canopies or other issues, especially when yield is divided by PAR. The 2020 data shows that not all large peach-almond hybrids produced comparable yields, and that not all small trees that weren't on peach x almond hybrids yielded poorly. Canopy light interception (PAR%) measurements show the rootstocks can be roughly grouped by size into peach x almond hybrids and everything else. Given their comparable size, it is somewhat surprising that trees on Hansen 536 yielded lower than those on Titan, Nickels, FxA and Brights 5. It seems from the data so far that not all peach x almond hybrids are equally suitable for high boron conditions.

Cumulative yield for the life of the trial (Figure 1). Over the years, FxA and Brights 5 have often had lower yields than Titan and Nickels, but in each year these differences were not large enough to distinguish performance statistically. However, adding up yields over the course of the last eight years, Nickels shows itself to be significantly higher yielding than Brights 5. Leaf nutrient analyses, bloom and hullsplit timing are also presented below.

Table 1. Almond boron rootstock trial results, 2019. Letters behind numbers indicate statistically significant differences (Tukey,  $\alpha=0.05$ )

Rootstock	Origin	Avg Yield (kernel lbs/acre)*	Hull B † (ppm)	Light Intercep't (% PAR)	Size Efficiency (Lbs/PAR)	Trunk Circum (inches 18" above soil)
Titan SG1	Peach-Alm	3,790	159	77	49	31
Nickels	Peach-Alm	3,788a	158 b	77 a	49	32 ab
FxA	Peach-Bitter Alm	3,693ab	148 b	80 a	46	33 a
Brights 5	Peach-Alm	3,305ab	178 b	71 ab	46	29 d
Viking	Pch-Al-Myro-Apr	2,911bc	167 b	64 bc	46	29 cd
Hansen 536	Peach-Alm	2,307cd	148 b	72 ab	32	31 bc
Krymsk 86	Myro Plum-Peach	2,278cde	168 b	54 cd	42	27 de
Rootpac-R	Myro Plum-Alm	1,961de	158 b	53 cd	37	29 cd
Lovell	Peach	1,475e	262 a	46 d	32	26 e

\*Per-acre yield based on average of 5 trees over 6 replications, scaled for the 110 trees per acre spacing. Titan SG1 Not replicates so statistical comparison made.

† > 300 ppm = "toxicity"

Figure 1. Boron rootstock trial cumulative yield for 3<sup>rd</sup> through 10<sup>th</sup> leaf (2013-2020). Scaled from the 5 tree sample average to per acre yields based on the 110 trees per acre spacing, with the exception of Titan. Letters indicate statistically significant differences (Tukey,  $\alpha=0.05$ )

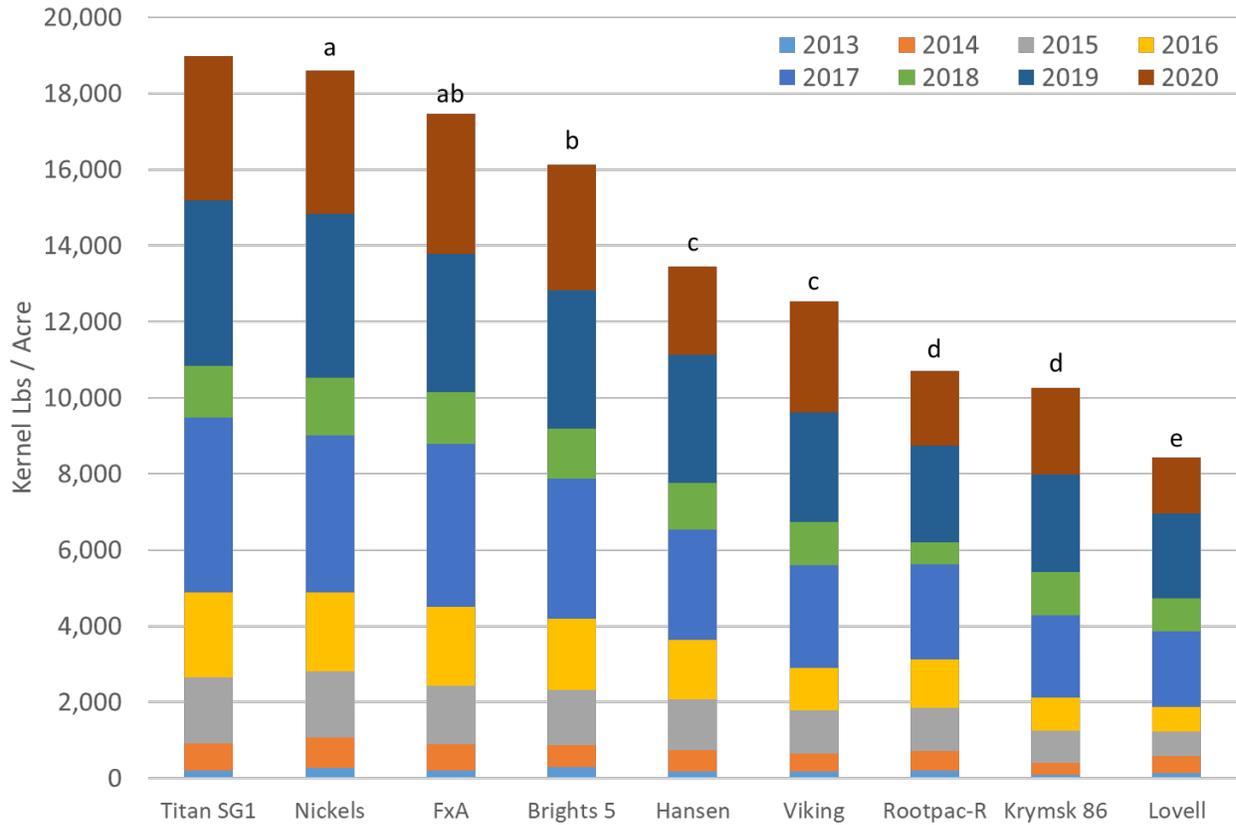


Table 2. Macronutrient Leaf analysis, 2020 (ordered by 2020 yields). Letters behind numbers indicate statistically significant differences (Tukey,  $\alpha=0.05$ )

	N (%)		P (%)		K (%)		S (ppm)		Ca (%)		Mg (%)	
TitanSG1	1.8		0.09		0.62		1255		3.0		1.4	
Nickels	1.9	abc	0.09	ns	0.88	ab	1325	ab	3.5	a	1.5	ab
FxA	2.0	a	0.09		1.02	a	1325	ab	3.4	a	1.5	ab
Brights5	1.9	a	0.09		0.71	ab	1372	ab	3.5	a	1.5	a
Viking	2.0	a	0.09		0.80	ab	1267	b	3.2	ab	1.3	ab
Hansen536	1.8	bc	0.09		0.87	ab	1235	b	3.5	a	1.5	ab
Krymsk86	1.9	a	0.09		0.74	ab	1440	a	3.0	b	1.3	ab
RootpacR	1.7	c	0.09		0.56	b	1325	ab	3.0	b	1.4	ab
Lovell	1.7	bc	0.09		0.63	b	1322	ab	2.3	c	1.3	b

Table 3. Micronutrient Leaf Analysis, 2020 (ordered by 2020 yields). Letters behind numbers indicate statistically significant differences (Tukey,  $\alpha=0.05$ )

	B (ppm)		Zn (ppm)		Mn (ppm)		Fe (ppm)		Cu (ppm)	
TitanSG1	34.0		21.6		19.5		112		3.2	
Nickels	34.5	b	28.3	abc	16.9	bc	111	ns	4.0	a
FxA	35.6	ab	39.1	a	23.5	abc	110		4.5	a
Brights5	36.6	ab	34.0	ab	29.0	a	109		3.9	ab
Viking	33.9	b	20.0	c	16.8	bc	104		3.9	ab
Hansen536	36.1	ab	31.5	ab	22.0	abc	117		3.6	ab
Krymsk86	33.6	b	27.4	bc	21.6	abc	116		3.7	ab
RootpacR	33.0	b	31.8	ab	25.7	ab	122		3.4	ab
Lovell	39.4	a	26.7	bc	14.5	c	110		2.8	b

Table 1. Mean bloom percent by rootstock variety, in three sampling dates, 2020. Letters behind numbers indicate statistically significant differences (Tukey,  $\alpha=0.05$ )

	02/14	02/18	02/24
TitanSG1	0	65	100
Nickels	0	77	100
FxA	0	67	100
Brights5	0	70	100
Viking	1	72	100
Hansen536	1	67	100
Krymsk86	1	55	100
RootpacR	2	67	100
Lovell	1	75	100

Table 5. Mean hull split levels by rootstock variety, in three sampling dates, 2020. (% at 2C or further progressed). Letters behind numbers indicate statistically significant differences (Tukey,  $\alpha=0.05$ )

	07/08	07/15	07/22
TitanSG1	3	20	100
Nickels	3	26	93
FxA	1	24	93
Brights5	2	17	94
Viking	14	90	100
Hansen536	0	10	96
Krymsk86	0	14	87
RootpacR	0	1	67
Lovell	83	97	100

#### D. Comparison of Almond Rootstocks and Cultivars Using Growth and Photosynthetic Parameters at Fresno State

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#### Project Cooperators and Personnel:

Madison Hedge, Research Assistant; Hardeep Singh, Graduate Research Assistant; Ranvir Tung, Graduate Research Assistant; Faranak Hadavi, Research Scientist; Masood Khezri, Research Scientist

#### Summary

Currently, there are several rootstock evaluation trial blocks in the Central Valley, evaluating rootstock / scion responses to abiotic and biotic stresses; however, there is a need for a trial where some of the semi-dwarfing and dwarfing rootstocks must be evaluated in terms of their influence on tree architecture, growth response, yield potential, and sustainability. With a long-term goal to provide the industry with an improved orchard system, rootstock-scion combinations, Cornerstone, Empyrean 1, Guardian, Lovell, Nemaguard, Rootpac 20, and Rootpac R grafted to Monterey and Nonpareil, are being evaluated for canopy structure and canopy light interception under new training systems. The almond rootstock evaluation growth habits and genetic composition trial at Fresno State is part of a larger effort to evaluate rootstock performance in a variety of conditions. The trial has eighty-four plots that have six replications for each of the seven rootstocks X Nonpareil or Monterey combinations. Cultivar combinations are evaluated for their performance based upon multiple ecophysiological parameters.

## 1. Objectives

1.1 Compare performance of conventional peach rootstocks 'Guardian' and 'Lovell' with peach almond hybrid rootstocks 'Cornerstone' (*P. dulcis* × *P. persica*) and 'Empyrean 1' and dwarfing rootstocks 'Rootpac-20' and 'Rootpac-R' on two different scions Nonpareil and Monterey in three different soil textures. 'Nemaguard', the industry standard, is used as the control on both Monterey and Nonpareil scions. This study evaluates water use efficiency, bloom timing, hull split timing, yield, dry kernel weight, K:H ratio, and the increase of trunk diameter.

1.2 A vs GSW. Comparing photosynthetic parameters for 3 rootstocks [Nemaguard (Peach rootstock, Industry standard). Cornerstone (peach x almond hybrid), and RootPac-20 (Hybrid, growth-controlling rootstock)] on two scions (Nonpareil and Monterey) on two different soil textures. Obtaining In-situ, light response, and carbon dioxide to measure Net Instantaneous Photosynthesis (A) and Stomatal Conductance (gsw).

## 2. Results and discussion

### 2.1 Hull Split

Hull split data taking on Nonpareil began on 6/29 and more than 1% of all Nonpareil was past Deep V (unsplit stage) and 80% reached 3/8<sup>th</sup> suture by 7/13. NP on Lovell was complete by 7/8, Cornerstone was complete by 7/9, Nemaguard and Rootpac 20 were complete 7/10, Guardian and RootpacR were complete 7/11, and Empyrean was complete 7/13. We can infer that the rootstock influenced hull split and Lovel had the earliest hull split while Empyrean1 had the latest.

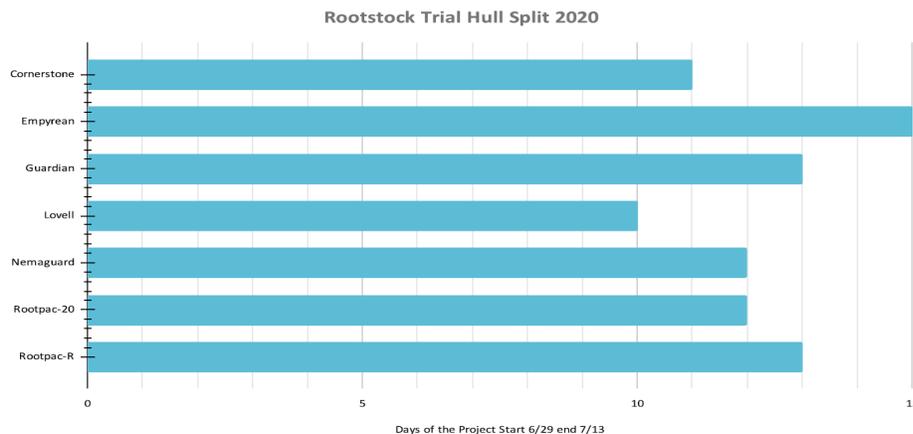


Figure 1. Shows Hull split analysis of rootstocks on Nonpareil

More than 1% of Monterey was past Deep V (start of separation) by 7/6-7/7 and 80% reached 3/8<sup>th</sup> suture by 8/14-8/15. Cornerstone, Guardian, and Nemaguard started 7/6 and was complete 8/14 (40 days) Empyrean and Lovell started 7/7 and were complete 8/15 (40 days), Rootpac20 started 7/6 and was complete 8/15 (39 days) and RootpacR started 7/7 and was complete 8/14. In Monterey hull split started earlier in Nemaguard, Guardian and Cornerstone

while Lovell and Empyrean had the late start.

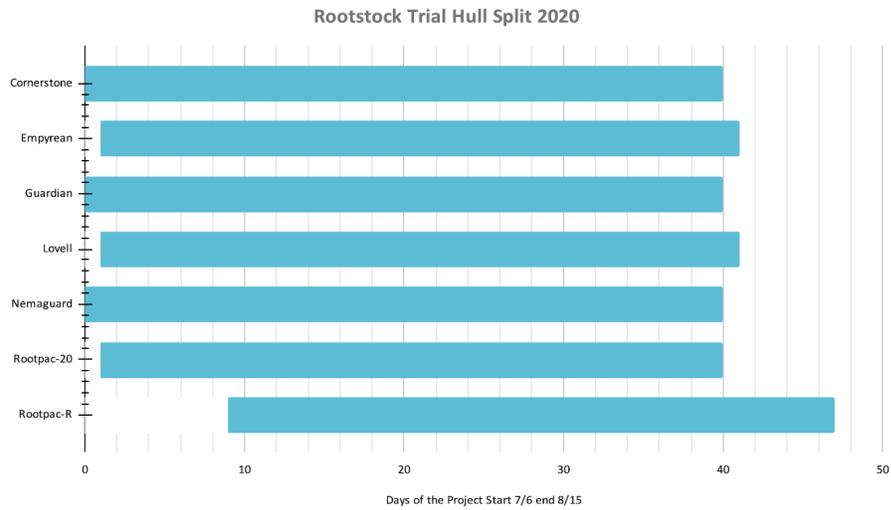


Figure 2. Hull split analysis of rootstocks on Monterey

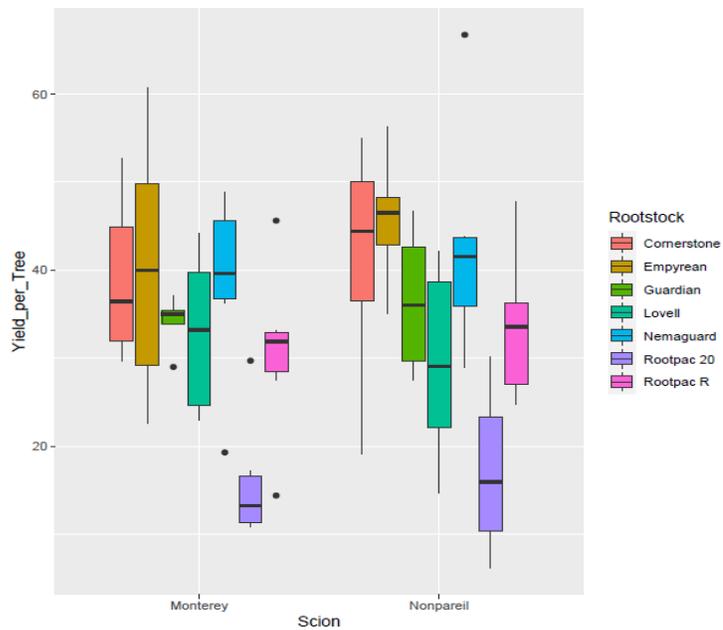


Figure 3: Yield per tree for all rootstock-scion combinations.

## 2.2 Yield

Monterey yielded slightly lower than Nonpareil on all rootstocks except Lovell. Rootstock yields highest to lowest with Nonpareil, Monterey values (lb per tree) in parenthesis: Emphyrean 1 (40, 46), Cornerstone (36, 44), Nemaguard, (39, 42), Guardian (35,36), Lovell (34, 29), RootpacR (32, 34), Rootpac20 (13, 16). Yield was highest on Emphyrean1 with both scions suggesting that Emphyrean is just as good (Monterey) or better (Nonpareil) performance than Nemaguard. On Nonpareil, Cornerstone yielded more than Nemaguard.

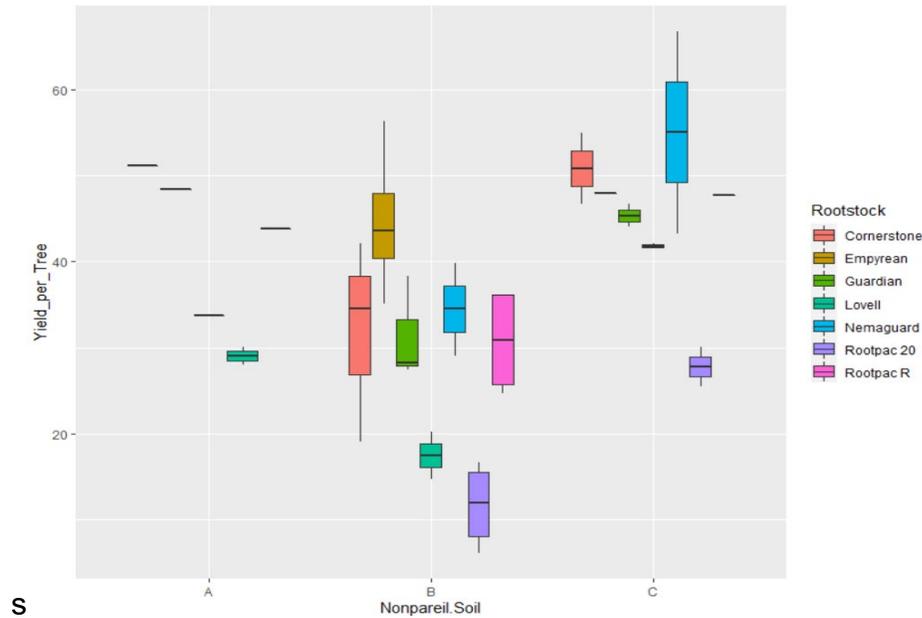


Figure 4: Nonpareil yield (lb per tree) on all rootstocks in 3 different soil zones.

### Soil differences seen in yield

Significant difference in yield is seen between various soil textures. This variation explains the outliers in figures 4 and 5. Highest to lowest yield in pounds on Nonpareil scions in each soil are as follows: Soil C Nemaguard (55) was the highest yielding of all, Soil A Cornerstone (51), Soil C Cornerstone (51), Soil A Emphyrean (49), soil C emphyrean (48), soil C RootpacR(48), Soil C guardian (45), soil A Nemaguard (44), soil B emphyrean (44), soil C Lovell (42), soil B cornerstone (35), soil B nemaguard (35), soil A guardian (34), soil RootpacR (32), soil A lovell (29), soil B guardian (28), soil C Rootpac20(27), soil B lovell (18), soil B Rootpac20 (13).

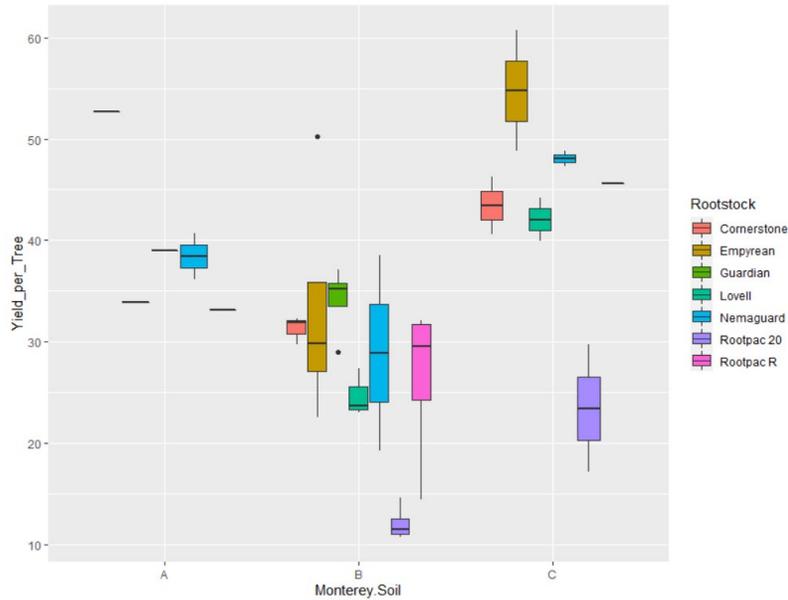


Figure 5: Monterey yield (lb per tree) on all rootstocks in 3 different soil zones.

Highest to lowest median yield in pounds on Monterey scions in each soil are as follows: soil C Empyrean (55), soil a Cornerstone (53), soil c Nemaguard (48), soil c RootpacR (46), soil c Cornerstone(43), soil c Lovell (42), soil a Guardian (39), soil a Nemaguard (38), Soil b Nemaguard (36), soil a Empyrean (34), soil a RootpacR(33), soil b Cornerstone (32), soil b Empyrean (30), soil b RootpacR (29), soil b Nemaguard (28), soil b Lovell (24), soil c Rootpac20 (23), and soil b Rootpac20 (12).

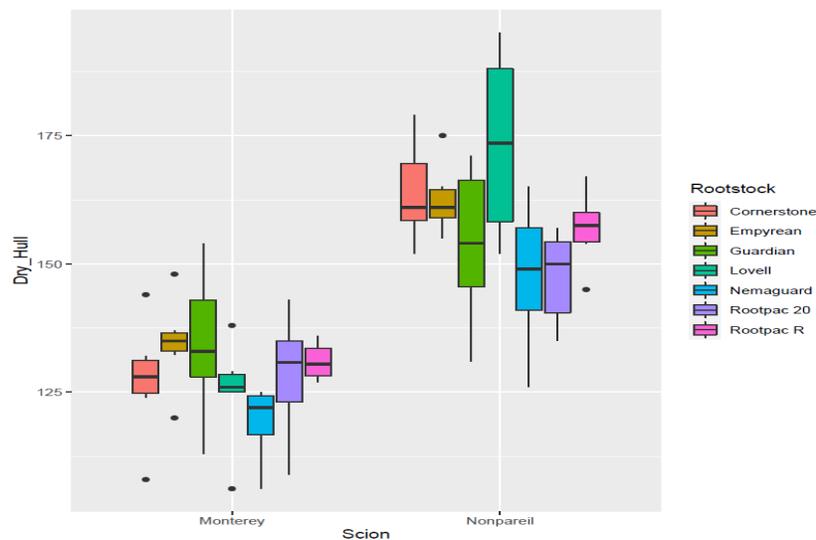


Figure 6: Hull dry weight

## 2.3 Hull, Shell, and Kernel Quality

**2.3.1 Hull.** The average dry weight of 100 hulls was more in Nonpareil than Monterey for all rootstocks. Cornerstone (164, 127), Empyrean (163, 135), Guardian (154, 134), Lovell (173, 125), Nemaguard (148, 119), Rootpac20 (148, 128), RootpacR (157, 132). Monterey had thinner, smaller hulls than Nonpareil.

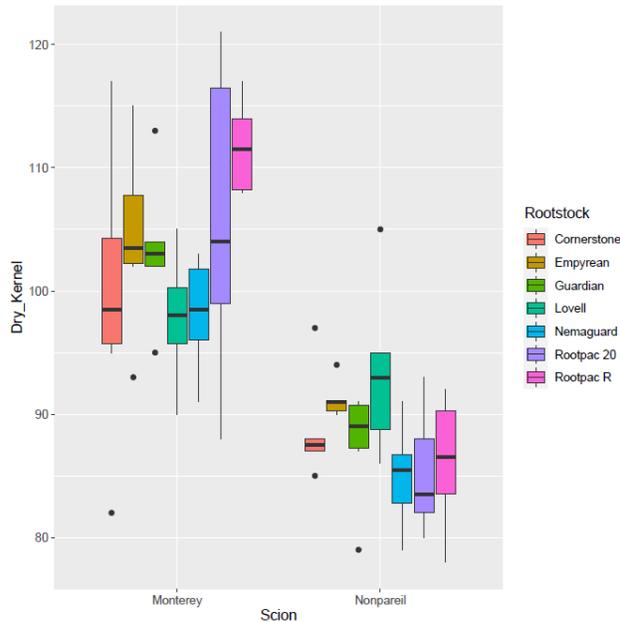


Figure 7. Kernel dry weight.

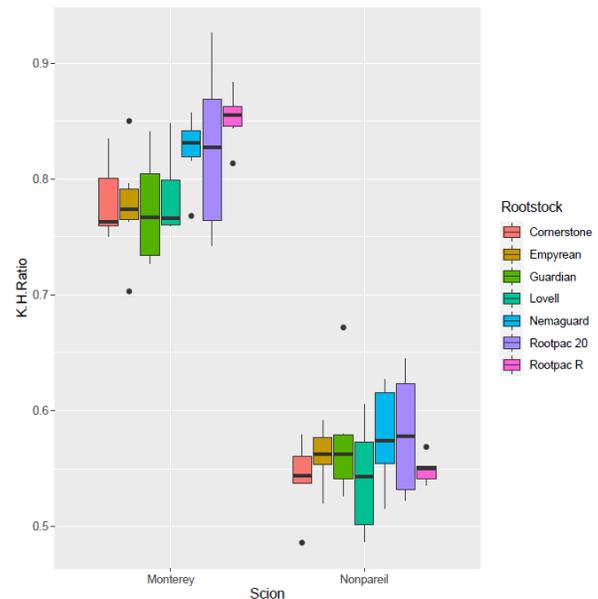


Figure 8. Kernel to hull ratio (as a percentage).

### 2.3.2 Kernel dry weight

Nonpareil on all rootstocks yielded much larger nuts than Monterey on all rootstocks resulting in a fewer number of nuts per pound. Within Nonpareil, Lovell (94g) had the highest weight per 100 nuts (larger nuts), followed by Empyrean 1 (91g), Cornerstone (89g), Guardian (88g), RootpacR (86g), Rootpac20 (85g), and Nemaguard (85g). Within Monterey, RootpacR (112g) had the highest weight per 100 nuts followed by Rootpac20 (106g), Empyrean (104g), Guardian (103g), Cornerstone (100g), Nemaguard (98g), and Lovell (98g).

### 2.3.3 Kernel: Hull Ratio (Dry weight basis)

Monterey on all rootstocks has a higher kernel to hull ratio (K:H ratio, dry weight basis) than all rootstock on Nonpareil overall (Figure 8). Nonpareil has a smaller, more favorable K:H ratio Cornerstone (0.54:1), Lovell (0.54:1), RootpacR(.55:1), Empyrean (.56:1), Guardian (.57:1), Nemaguard (.58:1), and Rootpac20 (.58:1). Monterey had larger less favorable K:H ratio Cornerstone (.78:1), Guardian (.77:1), Lovell (.78:1), Empyrean (.78:1), , Nemaguard (.82:1) Rootpac20 (.83:1), and RootpacR (.85:1).

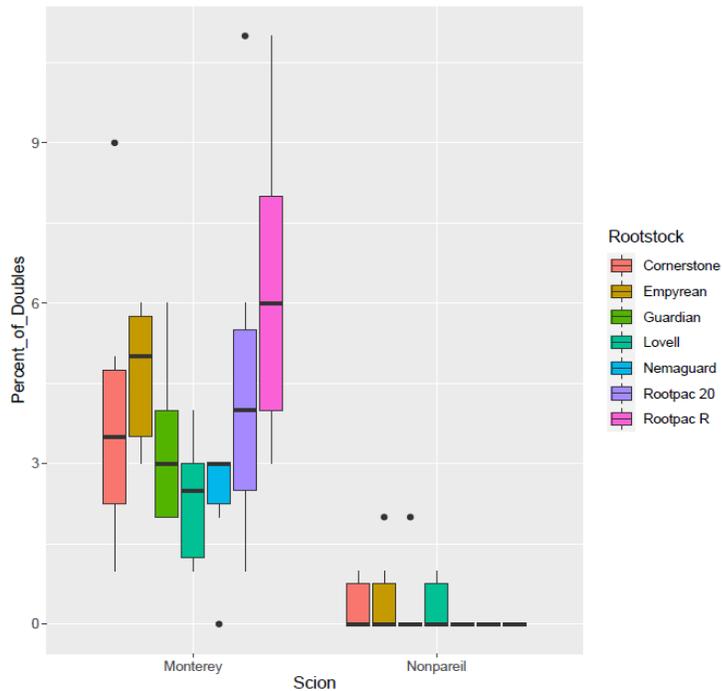


Figure 9. Percent of doubles for all rootstock-scion combinations.

### 2.3.4 Percent of Doubles

Figure 9 shows the percent of doubles for each pound harvested. Percent of doubles per pound by treatment was infrequent (less than 1% in 100 nuts) in Nonpareil as opposed to Monterey (more than 10% and up to ~21% in 100 nuts). Nonpareil had very few doubles (less than 1% if you exclude outliers): Cornerstone (0.33%), Empyrean (0.50%), Guardian (0.33%), Lovell (0.33%), Nemaguard (0%), Rootpac20 (0%), and RootpacR (0%). Nonpareil on Nemaguard, Rootpac20, and RootpacR had no doubles at all suggesting these are the superior cultivars. Monterey has more than 2 doubles per 100 nuts in every single treatment and on average rootstocks on Monterey had more than 3.96% doubles: Cornerstone (4%), Empyrean (4.67%), Guardian (3.4%), Lovell (2.33%), Nemaguard (2.33%), Rootpac20 (5.57%), RootpacR (5.40%).

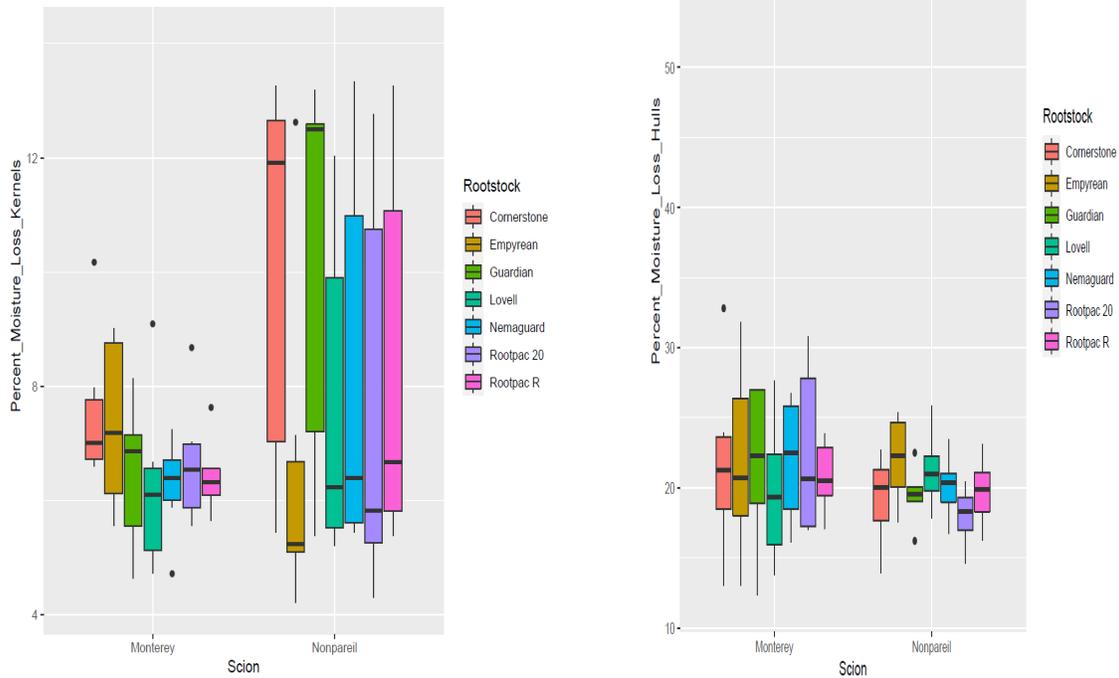


Figure 10. Percentage moisture loss kernels and hulls.

### 2.3.5 Percent Moisture Loss Kernels and Hulls

Nonpareil Cornerstone (10.14%), Emphyrean (6.78%), Guardian (10.27%), Lovell (7.70%), Nemaguard (7.87%), Rootpac20 (7.70%), and RootpacR (8.43%). Monterey Cornerstone (7.17%), Emphyrean (6.79%), Guardian (6.46%), Lovell (6.09%), Nemaguard (6.51%), Rootpac20 (6.69%), and RootpacR (6.50%). Nonpareil had a larger range of moisture loss likely because samples were processed faster than the Monterey samples, thus leaving the Monterey samples in the cold storage for a longer length of time and more accurately obtaining residual field moisture from harvest. Monterey hulls sitting in cold storage made them absorb moisture obstructing true moisture loss.

Hulls of Nonpareil: Cornerstone (19.20%), Emphyrean (28.52%), Guardian (19.46%), Lovell (21.29%), Nemaguard (20.10%), Rootpac20 (17.96%), and RootpacR (19.71%). Hulls of Monterey: Cornerstone (21.71%), Emphyrean (21.94%), Guardian (27.38%), Lovell (19.71%), Nemaguard (21.99%), Rootpac20 (22.26%), and RootpacR (20.84%).

## **E. Performance and Evaluation of Almond Rootstocks in the Southern San Joaquin Valley**

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### **A. Summary**

Trees were planted on October 22, 2019 in a fumigated soil. The experiment is part of a replanted orchard on a sandy loam soil where orchard recycling was performed. Also, high winds in this part of the valley are one of the biggest challenges. In the first growing season, trees grew well during the season and significant differences were observed after one full growing season. Titan SG1 expressed the biggest growth as expressed by the change in tree circumference; Krymsk 86 grew the least among all rootstocks. Flordaguard x Alnem growth was similar to most peach-almond hybrids. Growth of Flordaguard, which is resistant to peach rootknot nematode, was not statistically different from peach-almond hybrids, nor from Krymsk 86. We will be monitoring this rootstock for its horticultural characteristics and yield. We have not observed any nitrogen deficiency symptoms among different rootstocks which can be observed in replanted orchards where whole orchard recycling has been performed and adopted.

### **B. Objectives**

The objective of this trial is to compare different rootstocks and evaluate the effect of rootstocks on scion growth and yield in Kern County. Among the rootstocks that will be tested is Flordaguard which is recommended for peach growers in Florida where *Meloidogyne floridensis* was detected for the first time in the US. This experiment is also evaluating other rootstocks that was not evaluated under Kern County conditions.

### **C. Annual Results and Discussion**

Soil analysis did not show any abnormal results in the top 3 feet, except for potassium which was below normal range (Table 2). The topsoil (0-6") showed higher organic matter due to orchard recycling. Trees grew well during the season and significant differences were observed after one full growing season. Titan SG1 had the biggest change in tree growth expressed as change in trunk circumference. Also, Flordaguard X Alnem, and BB106 were not statically significant from Titan SG1. All other peach-almond hybrids (BB 106, Emphyrean-1, Hansen, BH5) were not statistically different from each other. However, Cornerstone had the least increase in tree growth among peach-almond hybrids. It is important to note that Hansen 536, and BH5 rootstocks are among the most planted rootstocks in Kern County. While Krymsk 86 had shown good anchorage in a previous experiment in Kern County, it showed the least growth among all rootstocks tested. Flordaguard ranked in the middle and was not statistically different from Hansen 536 and BH5, neither was it statistically different from Krymsk 86. However, this rootstock showed resistance to a population of peach rootknot nematode

(PRKN) in Florida. While this rootstock experiment is not going to test resistance for this nematode at this site since this site is free of this invasive nematode, the purpose of including this rootstock in this experiment is to measure its growth and how it is going to affect yield under Kern County conditions.

Leaf analysis did not show any nitrogen deficiencies (Table 4). In certain cases where orchard recycling is performed, trees may show nitrogen deficiency early in the first year's growth. In this experiment we did not witness any nitrogen deficiency symptoms, nor it was detected in leaf analysis. Leaf analyses will serve as a baseline for future leaf analyses as the trees grow in future seasons. No loss was recorded due to high winds, nor due to diseases, however, some of the trees need to be replaced due to bird damage. Starting next year, we will start taking stem water potential looking at differences between the different rootstocks.

#### **D. Outreach Activities**

None during this funding cycle. However, results regarding tree growth from the first year of this project were presented at the SJV almond day on January 14<sup>th</sup>, 2021.

#### **E. Materials and Methods:**

Nonpareil scion grafted on eleven rootstocks were planted on October 22, 2019 in a fumigated soil (Table 1). The experiment is part of a replanted orchard on a sandy loam soil at Tejon Ranch. Orchard recycling was performed at this site. High winds in this part of the valley are one of the biggest challenges. Some growers in that part of the county use Krymsk 86 as a rootstock based on a previous UC rootstock trial that showed this rootstock to have good anchorage characteristics. The experimental design is a Randomized Complete Block Design with 6 blocks and 7 trees per block. The orchard is planted at 22' x 16' spacing. Stem diameter measurements were taken to assess tree growth.

The soil at the experimental site is classified as sandy loam based on the soil map, and it is uniform across the experimental site. Soil samples were taken in May, 2020 at 6 inches, one, two, three, four, and down to five feet deep. Samples were also taken at two locations at those depths, the soil was taken within the tree row between trees, and between the rows (Table 2). Leaf analysis for nutrient content was performed in July. Leaves were collected from each rootstock from 4 blocks only (Blocks 2 to 5) and sent to Dellavalle Laboratory Inc in Fresno, CA. Soil samples were also analyzed at Dellavalle Laboratory Inc in Fresno, CA. All trees at the experimental site were monitored for tree loss due to diseases. Also, trees were monitored for any nutritional issues due to orchard recycling.

**Table 1. Rootstocks planted at the trial in Kern County**

1	Hansen 536	<i>P. persica</i> X <i>P. dulcis</i>
2	Brights hybrid 5	<i>P. persica</i> X <i>P. dulcis</i>
3	BB106	<i>P. persica</i> X <i>P. dulcis</i>
4	Cornerstone	<i>P. persica</i> X <i>P. dulcis</i>
5	Titan SG1 Clonal	<i>P. persica</i> X <i>P. dulcis</i>
6	Empyrean-1	<i>P. persica</i> X <i>P. davidiana</i>
7	Krymsk 86	<i>P. cerasifera</i> X <i>P. persica</i>
8	Rootpac R	<i>P. cerasifera</i> x <i>P. dulcis</i>
9	Viking	<i>P. persica</i> X ( <i>P. dulcis</i> ) X (( <i>P. cerasifera</i> x <i>P. armeniaca</i> ))
10	Flordaguard	
11	FxA	Flordaguard X Alnem

**Table 2.** Soil analysis of the experimental site within tree row or between tree rows at different soil depths . Samples were collected in May, 2020 and analyzed at Dellavalle.

Soil ID	OM (%)	pH	EC (dS/m)	Ca (meq/l)	Mg (meq/l)	Na (meq/l)	Cl (meq/l)	PO <sub>4</sub> -P (mg/kg)
Tree 00-06"	1.09	7.6	1.38	6.2	2.2	4.1	2.6	14
Tree 06-12"	1.03	7.6	1.80	10.4	3.4	4.0	2.8	10
Tree 12-24"	0.90	8.0	1.27	6.9	2.0	3.2	2.5	5
Tree 24-36"	0.85	8.0	1.32	6.8	1.4	4.6	2.3	3
Tree 36-48"	0.79	8.0	1.31	5.3	1.0	5.8	2.4	3
Tree 48-60"	0.77	8.1	1.46	6.5	1.2	6.4	2.1	2
Middle 00-06"	1.49	7.5	1.31	6.4	3.0	2.8	0.4	13
Middle 06-12"	1.25	7.5	1.56	7.3	3.1	4.3	0.8	8
Middle 12-24"	0.91	7.8	1.45	5.9	1.8	5.4	0.6	4
Middle 24-36"	0.95	8.0	1.96	5.5	1.1	11.2	2.4	3
Middle 36-48"	0.93	8.1	1.66	4.0	0.7	10.1	2.2	3
Middle 48-60"	0.69	8.0	1.81	4.4	0.7	11.5	2.8	2

**Table 3.** Table 3. Mean change in trunk circumference (cm). The change was calculated by calculating the change in tree diameter since planting. Nonpareil scions were grafted on 11 different rootstocks. Different letters indicate significant differences at  $p < 0.05$  using Tukey-Kramer HSD.

Rootstock	Mean increase in trunk circumference (cm)
Titan SG1	11.87 A
FXA	10.37 AB
BB106	10.32 AB
Empyrean-1	9.48 BC
Hansen 536	9.26 BCD
BH5	9.25 BCD
Flordaguard	8.20 CDE
Rootpac R	7.60 CDE
Viking	7.42 DE
Cornerstone	7.29 E
Krymsk 86	7.22 E

**Table 4.** Leaf analysis of macro nutrients (N, P, K). Leaves were collected in July 2020 and processed at a commercial lab. Different letters indicate significant differences at  $p < 0.05$  using Tukey-Kramer HSD

Rootstock	N (%)	P (%)	k (%)
Titan SG1	2.80 A	0.16 A	1.76 AB
BB106	2.64 AB	0.15 A	1.46 CDE
FXA	2.63 AB	0.15 A	1.56 BCD
Krymsk 86	2.62 AB	0.16 A	1.81 AB
Empyrean-1	2.61 AB	0.15 A	1.27 E
Hansen 536	2.57 AB	0.16 A	1.42 DE
BH5	2.52 AB	0.15 A	1.35 DE
Rootpac R	2.50 AB	0.15 A	1.86 A
Flordaguard	2.45 B	0.15 A	1.79 AB
Cornerstone	2.44 B	0.15 A	1.43 DE
Viking	2.35 B	0.14 A	1.71 ABC