Research Update: Reaching Potential and Sustainable Yields
Session Speakers

Sebastian Saa, ABC
Bruce Lampinen, UC ANR
Roger Duncan, UC ANR
Katherine Jarvis-Shean, UC ANR
Franz Niederholzer, UC ANR
Research Update: Reaching Potential and Sustainable Yields

Moderator, Sebastian Saa, Senior Manager, ABC
Yield potential \(\frac{\text{lbs}}{\text{acre}}\) = No. of flowers \times \% of fruit set \times kernel weight
Research Update: Nutrient Management

• Bruce Lampinen, Specialist, UC Davis
  – Light interception and yield potential

• Roger Duncan, UC Cooperative Extension
  – Maximizing yield potential in the short and long-term

• Katherine Jarvis-Shean, UC Cooperative Extension
  – Training your orchard for potential and sustainable yields

• Franz Niederholzer, UC Cooperative Extension
  – Maintaining your orchard for best results
Reaching Potential and Sustainable Yields

Light Interception and Yield Potential
Bruce Lampinen, UC Davis Plant Sciences/UCANR
2<sup>nd</sup> Generation mule light bar

- Protective cage
- GoPro camera
- LIDAR
- 3D tilt sensor
- GPS antenna
- Datalogger
- PAR sensors
- Infrared thermometers
- Spring loaded section

Adjustable from 5 to 32 feet in width
Normal speed of travel is about 7 mph so we can map about 14 miles within 1 hour of the time the sun is directly overhead.

We set up a portable weather station with temp, RH, windspeed and PAR sensors outside orchard.

PAR = photosynthetically active radiation (in the wavelengths that drive photosynthesis)
Self contained hydraulic system for operating augers, autosampler and elevator

Trimble GPS acts as datalogger to collect continuous yield data

Front skirt to prevent nuts from overflowing as cart fills

Wireless controller for hydraulically operated auto sampler
We have found the best managed orchards (but very few) can alternate around this line (50 kernel lbs/1% intercepted) after about 5 years of age.

Regression through all data (40 kernel lbs/1% intercepted)
39% interception (2000 kernel lbs/ac potential)
50% interception (2500 kernel lbs/ac potential)
80% interception (4000 kernel lbs/ac potential)
90% interception (4500 kernel lbs/ac potential)
39% interception (2000 kernel lbs/ac potential)

50% interception (2500 kernel lbs/ac potential)

We do not recommend getting above this level of interception due to food safety concerns.

80% interception (4000 kernel lbs/ac potential)

90% interception (4500 kernel lbs/ac potential)
How does pruning and within tree row spacing influence yield potential?

Stanislaus County Spacing/Pruning Trial (Duncan)

Planted fall, 1999
Four spacings (10’ x 22’, 14’ x 22’, 18’ x 22’, 22’ x 22’)
Four pruning strategies

- **Conventional Pruning**
  - Three scaffolds
  - Annual pruning

- **Minimal training & pruning**
  - 4-6 scaffolds
  - Maximum of 3 cuts each year thereafter

- **Untrained, unpruned**
  - No scaffold selection
  - No annual pruning*
The closer the in-row tree spacing, the higher the light interception. Light interception tended to peak at 11 years of age at all in row tree spacings.
What about super high density plantings on dwarfing rootstocks - can they be more productive?

Grower trial: Super high density almond planting on dwarf rootstock holds promise
PAR = photosynthetically active radiation

121 trees/acre (18’ x 20’)

818 trees/acre (5’ x 11’)

Weather station PAR

PAR interception

PAR interception x incoming PAR
Yield potential based on midday PAR interception

<table>
<thead>
<tr>
<th>Planting</th>
<th>Midday PAR int. (%)</th>
<th>Yield potential (kernel lb/acre)</th>
<th>Actual yield (kernel lb/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5’ x 11’</td>
<td>44</td>
<td>2200</td>
<td>1324</td>
</tr>
<tr>
<td>18’ x 21’</td>
<td>83</td>
<td>4150</td>
<td>~3600</td>
</tr>
</tbody>
</table>
Excessive vegetative growth in response to hedging on top and sides

Mechanical and disease damage
Repeated hedging cuts leads to increased disease potential and lots of big wood that can cause damage to harvester.
Still need to fit an 8’ plus wide bankout wagon
8’ + 2.6’ = 10.6’

Yield potential for 8’ drive row and 2.6’ canopy width

\[
\frac{2.6}{10.6} \times 100 = 24.5 \% \text{ interception}
\]

24.5\times 50 = 1,225 \text{ kernel pounds per acre}
Over the row grape harvester

**Advantages**
- Eliminates dust generated by sweeping
- Minimizes harvest dust
- Reduces food safety risk since nuts do not touch the ground

**Disadvantages**
- Tree size is limited
- All tree surfaces are disturbed by hedging/topping
- Still requires a bankout wagon pulled by tractor in adjacent row
- Nuts still need to be dried

Wrap around harvester

**Advantages**
- Eliminates dust generated by sweeping
- Cleaner windrows
- Half as many windrows to pick up

**Disadvantages**
- Nuts still come into contact with ground
- Still requires dusty harvest pickup operation although likely cleaner

Tenias over the row harvester

**Advantages**
- Eliminates dust generated by sweeping
- Could be scaled up to larger trees
- With all equipment operating over the row, PAR interception could be higher

**Disadvantages**
- Somewhat slower to operate
- Hulls have value but are left in orchard
<table>
<thead>
<tr>
<th>Row width (a)</th>
<th>Drive middle (b)</th>
<th>Potential PAR interception (%)</th>
<th>Yield potential (lbs/acre)</th>
<th>Potential yield increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>With 8’ drive row</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10’</td>
<td>8’</td>
<td>20</td>
<td>1,000</td>
<td></td>
</tr>
<tr>
<td>12’</td>
<td>8’</td>
<td>33</td>
<td>1,650</td>
<td></td>
</tr>
<tr>
<td>14’</td>
<td>8’</td>
<td>43</td>
<td>2,150</td>
<td></td>
</tr>
<tr>
<td>With 4’ drive row</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10’</td>
<td>4’</td>
<td>60</td>
<td>3,000</td>
<td>+2,000</td>
</tr>
<tr>
<td>12’</td>
<td>4’</td>
<td>80</td>
<td>3,300</td>
<td>+1,650</td>
</tr>
<tr>
<td>14’</td>
<td>4’</td>
<td>86</td>
<td>3,550</td>
<td>+1,400</td>
</tr>
</tbody>
</table>
Costs of trees and irrigation system parts are higher with higher density.

Number of passes required for each orchard operation increases:

- Mowing
- Spraying
- Harvest
Spacing
Higher density plantings do not necessarily result in higher yields at some point as row spacing gets closer together since more space is devoted to drive rows.

There is a possibility of getting decent yields with high density plantings if we can:
- Develop effective dwarfing rootstocks
- Conduct all orchard operations with over the row equipment (and/or very small tractors)

We need to research food safety implications of high density plantings

18’ x 20’ tree spacing

Hard to convince growers to switch to high density plantings when they can get 4000 kernel pounds per acre with current plantings
Questions?

Thanks to the Almond Board of California for supporting this work.
Maximizing yield potential in the short and long-term

Roger Duncan
UC Cooperative Extension
Stanislaus County
Maximizing Almond Yield is Simple in Theory:

Maximum Light Interception = Maximum Yield Potential

Every 1% increase in light interception = 50 pounds per acre higher yield potential
Reality
How do we develop the problem-free 5000 pound orchard?

- Preplant site evaluation and modification
  - Physical, chemical, biological
- Rootstock, variety, tree spacing and proper planting and after planting care (irrigation, fertility, etc.)
Stratified sandy loam soil – restricts water movement through soil profile
Soil layers restrict root development & water infiltration
Loamy soil over coarse sand – 90 minute wetting
Loamy soil over coarse sand – water moves through only after upper layer saturated
# Replant Problems of Almonds: Fumigant Option Overview

<table>
<thead>
<tr>
<th>Problem</th>
<th>Fumigant</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Nematode Parasitism</td>
<td>Telone-II (Chloropicrin)</td>
<td>Broadcast or Row Strip</td>
</tr>
<tr>
<td>Low/Medium Nematode Parasitism</td>
<td>Telone-II (Chloropicrin)</td>
<td>Row Strip (Spot?)</td>
</tr>
<tr>
<td>Nematode Parasitism + Prunus Replant Disease (PRD)</td>
<td>Telone-II Telone-II C35</td>
<td>Broadcast Rowstrip, Spot</td>
</tr>
<tr>
<td>PRD Only</td>
<td>Chloropicrin</td>
<td>Spot, Rowstrip</td>
</tr>
</tbody>
</table>

Courtesy of D. Doll
Choose Appropriate Rootstock

Think of the rootstock as your DEFENSE against problems which will prevent your orchard from obtaining full potential
Specific Challenges

High pH / Salt / Alkali

➢ Peach / Almond Hybrids
   • Hansen, Nickels, Brights Hybrid, Titan, Cornerstone

➢ Viking

➢ Empyrean #1
Specific Challenges

Ring Nematodes / Bacterial Canker

➢ Viking
➢ Lovell
➢ Guardian
➢ Empyrean 1
Specific Challenges

Heavy Soil / “Wet Feet” / Phytophthora

- Krymsk 86
- Rootpac R
- Marianna 2624
10' x 22' hedgerow

22' x 22' offset
The Effect of In-row Tree Spacing on Cumulative Yield Through 20th Season
Nonpareil on Nemaguard

Cumulative Yield (lb/acre)

10’ x 22’: 48,021 lb/a
14’ x 22’: 47,488 lb/a
18’ x 22’: 45,923 lb/a
22’ x 22’: 42,540 lb/a

Highest long-term yields 10 – 14 foot spacing.
The Effect of Tree Spacing on Cumulative Yield Through 11th Leaf Nonpareil on Hansen

No significant difference between different trees spacings for first 10 – 11 years.
The Effect of Tree Spacing on Cumulative Yield Through 20\textsuperscript{th} Leaf
Nonpareil on Hansen

- Moderate spacing may be best for large variety on vigorous rootstock.
- Risk is low of planting trees too close.
The Effect of Tree Spacing on Cumulative Yield Through 19th Season
Carmel on Nemaguard

Smaller variety on medium vigor rootstock: Cumulative yield directly related to tree spacing.

Roughly 5.8% increase in cumulative yield for each 4’ decrease in in-row tree spacing.
Effect of In-row Tree Spacing & Rootstock on Tree Size.

Tree size heavily influenced by spacing; closely planted trees are smaller.
Hansen & Nemaguard similar size at tight spacings.
The Effect of Tree Spacing on Scaffold Splitting of Almond Trees

- Tree failure was most severe in widely planted (large) trees (5th leaf).
- Tree spacing had larger impact on tree failure than pruning.
The Influence of Tree Spacing on the Number of Replanted Trees

(on all 37 acres)

Number of Replanted Trees

- 19th leaf
- 16th leaf
- 15th leaf
- 14th leaf
- 13th leaf
- 12th leaf
- 10th leaf
- 9th leaf
- 8th leaf
- 6th leaf

Distance between trees:
- 10' x 22'
- 14' x 22'
- 18' x 22'
- 22' x 22'
Costs of Higher Density

• For every one foot reduction in row width (e.g., 22’ to 21’), many costs are increased by 5%

  – Strip fumigation, mowing, spraying, herbicides, irrigation hoses, sprinklers, etc.

  – Planting trees closer down the rows does not increase most on-going costs
Summary

Spend your money prior to planting to keep your orchard growing uniformly

- Preplant soil modification & disinfection
- Proper rootstock and planting configuration
  - If in doubt, choose more vigor and higher density
- “Proper” irrigation & fertility
Thank you for your attention

Roger Duncan
209-525-6800
raduncan@ucdavis.edu
cestanislaus.ucdavis.edu

University of California
Agriculture and Natural Resources
Almond Tree Training

Katherine Jarvis-Shean
UCCE Orchard Systems Advisor
Sacramento, Solano & Yolo Co.s
Goal of Training (Years 1-3)

Create structure to support crop weight  
Minimize cuts that decrease early yields

Minimize infection: Avoid rain, January for fastest healing, Protect with appropriate fungicide
Heading At Planting: Most important cut in tree’s life

**Goal:** Room for 4-6 scaffolds above ~22” for shaker head.

- If ideal is 6” per Scaffold → Ideal = +24-36” above shaker head zone

Potted: If < 42” of trunk growth...

- If fall planted, let it grow, then top like new bare root when dormant.
- If winter or spring planted, tip if untipped, let it grow and scaffold select at first dormant.

Bare Root: Top at 42-48” for scaffolds spacing.
Training Young Trees: 1\textsuperscript{st} Dormant – Scaffold Selection

\textit{Selection Goal:} Strong, well anchored branches that won’t break or split from trunk with future crop weight.

• 1\textsuperscript{st}: Remove crosses, shaker blockers
• 2\textsuperscript{nd}: Pick the best of what’s left
  • Angle, Spacing, Orientation
• 3\textsuperscript{rd}: Head back \sim 20-30%
  • Longer \rightarrow Potential roping
How Many Scaffolds? Stanislaus Co.

Photosynthetically Active Radiation (PAR)

Untrained, Unpruned
4-6 Scaf, 3 cuts annually
3 Scaf, Unpruned
3 Scaf, Conv. annual Pruning
Training Young Trees: 2\textsuperscript{nd} Dormant

Example: 5 Scaffolds

✓ 1\textsuperscript{st}: Remove trouble-makers
  ✓ Cross, Central, Smackers

✓ 2\textsuperscript{nd}: Select 2ndary scaffolds
  ✓ 2+ off primary
  ✓ Angle & Spacing
  ✓ Vigorous, up & out, well spaced.

• Heading not necessary
Training Young Trees: 3\textsuperscript{rd} Dormant

- Minimal-to-no pruning required at this stage.
- 1\textsuperscript{st}: Remove crossed limbs.
- 2\textsuperscript{nd}: Remove tractor smackers.
- 3\textsuperscript{rd}: Remove yourself and crew. Most pruning at this point will delay early yields.
Franz Niederholzer, UC ANR
Once its built, strong & complete, maintain the orchard for best results.
Orchards are like kids. You can set them up but shouldn’t try to make it happen.
The goal is consistent production.
The objectives are:

• adequate pollination/nut set
• careful irrigation & nutrition
• protect the canopy
Good bee activity + adequate boron = good nut set. All hives are not equal.

<table>
<thead>
<tr>
<th>Frames/hive</th>
<th>Pollen collected (lb per hive)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>0.51</td>
</tr>
<tr>
<td>5</td>
<td>0.67</td>
</tr>
<tr>
<td>6</td>
<td>1.17</td>
</tr>
<tr>
<td>8</td>
<td>1.70</td>
</tr>
</tbody>
</table>

Sheesley & Poduska, CalAg 1970
Good bee activity + adequate boron = good nut set.

<table>
<thead>
<tr>
<th>Hull boron (ppm)</th>
<th>Boron status</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;80</td>
<td><strong>Deficient</strong></td>
</tr>
<tr>
<td>80-120</td>
<td><strong>Could use +B</strong></td>
</tr>
<tr>
<td>120-200</td>
<td><strong>Adequate?</strong></td>
</tr>
<tr>
<td>&lt;300</td>
<td><strong>Toxic</strong></td>
</tr>
</tbody>
</table>
Careful irrigation to match orchard water use.

Normal Year Monthly CIMIS ETo for S. San Joaquin Valley

Acre inches

Blake Sanden, UCCE (retired)
With the crop set, feed it. Focus on nitrogen, don’t ignore potassium.

Leaf N target 2.4-2.5%
Leaf K target 1.4% (deficient <1%)
Check leaf levels in spring and summer.
Use the 4-Rs
Multiple applications better than bigger “shots”
Maintain a healthy canopy. Keep the motor running smoothly.

- Irrigation (previously noted, but worth repeating)
- Disease control
  - Monitoring (Weather & Crop)
  - Materials/Rotation
  - Coverage
- Mite control
  - Monitoring (Weather & Crop)
  - Materials/Rotation
  - Coverage
Opinion: Don’t try to out smart Nature (AKA Don’t plan your kids’ lives).
Session Review
Thank you!