Production Efficiency
Trends & Opportunities

Greenhouse Production of Floriculture Crops
- Mature market
- Consolidation
- Competition

- OK, we get it...
- Focus on labor & economic efficiency

Pre-rooted cuttings & direct sticking
- URC v Callused cuttings to produce a rooted liner
- Rooted liner or direct stick callused to finish 4-in pot

Pre-rooted cuttings & direct sticking
- URC v Callused cuttings to produce a rooted liner

Juan Carlos Vallejo tested bracteantha, geranium, osteos, scaevola (2 suppliers over 2 years)
- Average 1 week longer to produce rooted liner from URC v callused cutting

To produce a rooted liner
(Yes, this is the only budget you have to sit through!)

<table>
<thead>
<tr>
<th>Crop name</th>
<th>URC</th>
<th>Callused cuttings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plants per container</td>
<td>162</td>
<td>162</td>
</tr>
<tr>
<td>Cost per cutting</td>
<td>$5.34</td>
<td>$5.44</td>
</tr>
<tr>
<td>Cost of cuttings per container (square feet)</td>
<td>$34.68</td>
<td>$44.88</td>
</tr>
<tr>
<td>Container area (square feet)</td>
<td>1.7</td>
<td>1.7</td>
</tr>
<tr>
<td>Weeks to produce a rooted liner</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Total area time (square foot weeks)</td>
<td>9.1</td>
<td>6.7</td>
</tr>
<tr>
<td>Overhead cost per square foot week</td>
<td>$6.60</td>
<td>$6.60</td>
</tr>
<tr>
<td>Overhead cost (per container)</td>
<td>$5.04</td>
<td>$4.93</td>
</tr>
<tr>
<td>Other direct costs per container/container (greening media and labor to transport)</td>
<td>$3.98</td>
<td>$3.98</td>
</tr>
<tr>
<td>Total costs before shrinkage (Overhead + other direct costs + cuttings)</td>
<td>$43.70</td>
<td>$52.69</td>
</tr>
<tr>
<td>Shrinkage (5, in %)</td>
<td>5.5%</td>
<td>6.0%</td>
</tr>
<tr>
<td>Additional cost of shrinkage</td>
<td>$2.08</td>
<td>$2.60</td>
</tr>
<tr>
<td>Total cost after shrinkage (per container)</td>
<td>$49.78</td>
<td>$55.25</td>
</tr>
<tr>
<td>Sales price per rooted liner</td>
<td>$5.57</td>
<td>$6.17</td>
</tr>
<tr>
<td>Sales price (per container)</td>
<td>$58.14</td>
<td>$61.14</td>
</tr>
<tr>
<td>Net revenue (per container)</td>
<td>$52.57</td>
<td>$54.97</td>
</tr>
<tr>
<td>Net revenue per square foot week</td>
<td>$5.47</td>
<td>$6.07</td>
</tr>
</tbody>
</table>

- URC generally more profitable than callused to produce an rooted liner tray

<table>
<thead>
<tr>
<th>URC</th>
<th>Callused cuttings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower plant material cost</td>
<td>$0.10 higher plant cost</td>
</tr>
<tr>
<td>1 week longer</td>
<td>1 week shorter</td>
</tr>
<tr>
<td>4.5% shrinkage</td>
<td>0.7% shrinkage</td>
</tr>
</tbody>
</table>

Pre-rooted cuttings & direct sticking
- Rooted liner or direct stick callused to finish 4-in pot

Pre-rooted cuttings & direct sticking
- Rooted liner generally more profitable than callused to produce a 4-in pot during peak because of $/sfw, but balance changes in off-peak

To produce a 4-in pot
- Rooted liner generally more profitable than callused to produce a 4-in pot during peak because of $/sfw, but balance changes in off-peak

<table>
<thead>
<tr>
<th>Rooted liner</th>
<th>Callused</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0.13 higher plant cost</td>
<td>$0.13 lower plant cost</td>
</tr>
<tr>
<td>3 weeks shorter</td>
<td>3 weeks longer</td>
</tr>
<tr>
<td>0% shrinkage</td>
<td>0.5% shrinkage</td>
</tr>
</tbody>
</table>
Pre-rooted cuttings & direct sticking

- Rooted liner v Basewell cuttings to finish a 4-in pot

- Sofia Flores tested bacopa, calibrachoa, NG Impatiens, portulaca (2019)
- Average 1 week extra to product 4-in pot from direct stick of Basewell v rooted liner
- At $0.30 labor plus overhead per square foot week, Basewell breaks even at 85% of rooted liner cost
- At $0.60/sfw peak, rooted liners more favored

Guidelines on URC v callused, liner v direct stick

- Key variables: plant cost, crop time, labor & overhead cost/sfw, shrinkage
- When producing a rooted liner tray, the biggest cost is plant material. Use URCs unless there is a lot of shrinkage
- For finished plants:
  - During the peak season: crop time rules
  - During the off-peak: low material cost rules
- Use our spreadsheet tool
- Direct transplant can reduce labor and material costs by eliminating the rooted liner step. For that, we need accurate enterprise budgets (Megh’s project in 2019)

Manual Labor Cost Per Cutting

- Mean: $0.023 per cutting from receiving to laying down cutting
- Labor cost break down:
  - Transplanting cutting into tray 70%
  - Supervising 10%
  - Moving cuttings 8%
  - Filling trays 8%

Baseline scenario with all manual transplant

- 31.8 Million cuttings transplanted
- Peak week 4 workers: 59 FTE transplanted 2.1M, planting 897 cuttings/hour
- Hourly wage: $12.49
- Labor cost: $442,650
- Cost per cutting to insert a cutting into a tray: $0.014

ROI for Automatic Transplanting of Plant Cuttings

- 31.8 Million cuttings transplanted
- Peak week 4 workers: 59 FTE transplanted 2.1M, planting 897 cuttings/hour
- Hourly wage: $12.49
- Labor cost: $442,650
- Cost per cutting to insert a cutting into a tray: $0.014

ROI: Spreadsheet tool

Cart loader

Grower Ingenuity To Save Labor — KubePak Basket (and Fingernail) Trimmer
3. Optimize labor
- Let's not forget manual transplanting
- Wide range of productivity between companies & individuals
- Is this good technique?

Can we identify the best method and provide training?

Tracking hand movement: Initial research with video analysis

<table>
<thead>
<tr>
<th>Cell</th>
<th>Time(s)</th>
<th>Speed (in/s)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.60</td>
<td>23.22</td>
<td>From the top of the tray</td>
</tr>
<tr>
<td>2</td>
<td>0.86</td>
<td>13.66</td>
<td>27:20-28:06</td>
</tr>
<tr>
<td>3</td>
<td>0.77</td>
<td>14.52</td>
<td>30:23-31:46</td>
</tr>
<tr>
<td>4</td>
<td>0.80</td>
<td>9.75</td>
<td>31:93-32:53</td>
</tr>
<tr>
<td>5</td>
<td>0.70</td>
<td>8.04</td>
<td>34:13-34:96</td>
</tr>
<tr>
<td>6</td>
<td>0.77</td>
<td>8.61</td>
<td>36:23-37:03</td>
</tr>
<tr>
<td>7</td>
<td>0.86</td>
<td>2.67</td>
<td>39:70-40:40</td>
</tr>
<tr>
<td>8</td>
<td>1.17</td>
<td>13.22</td>
<td>From the top of the tray</td>
</tr>
<tr>
<td>9</td>
<td>1.40</td>
<td>9.64</td>
<td>44:40-45:80</td>
</tr>
<tr>
<td>10</td>
<td>3.17</td>
<td>3.83</td>
<td>46:33-49:50</td>
</tr>
<tr>
<td>11</td>
<td>1.33</td>
<td>7.57</td>
<td>50:13-51:46</td>
</tr>
<tr>
<td>12</td>
<td>1.03</td>
<td>7.86</td>
<td>53:23-54:26</td>
</tr>
<tr>
<td>13</td>
<td>1.36</td>
<td>5.61</td>
<td>55:30-56:66</td>
</tr>
<tr>
<td>14</td>
<td>0.86</td>
<td>7.17</td>
<td>57:30-58:16</td>
</tr>
</tbody>
</table>

Tracking hand movement: Proposed research with 3D sensors

It is not a new idea

Optimizing labor: training
- Best ROI is to train existing staff

<table>
<thead>
<tr>
<th>Course Subjects and Dates</th>
<th>Start</th>
<th>End</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greenhouse SE</td>
<td>4 Apr</td>
<td>29 Jun</td>
<td>—</td>
</tr>
<tr>
<td>Locking and Profitability</td>
<td>6 Apr</td>
<td>29 Jun</td>
<td>—</td>
</tr>
<tr>
<td>Nutrient Management 1 (fig)</td>
<td>2 Jul</td>
<td>31 Jul</td>
<td>—</td>
</tr>
<tr>
<td>Hydroponics Management</td>
<td>26 Jul</td>
<td>24 Aug</td>
<td>—</td>
</tr>
<tr>
<td>Nutrient Management 2 (sequel)</td>
<td>3 Nov</td>
<td>30 Sep</td>
<td>—</td>
</tr>
<tr>
<td>Disease Management</td>
<td>1 Dec</td>
<td>31 Dec</td>
<td>—</td>
</tr>
<tr>
<td>Shelf Quality &amp; Total Mix, NLP</td>
<td>3 Nov</td>
<td>7 Dec</td>
<td>—</td>
</tr>
</tbody>
</table>

Greensense

- Greenhouse Training Online
- 2018: 600 registrants so far, 8 courses
- 2018 ASHS award, American Floral Endowment grant
- Likely new course developments 2019-20 in substrates & irrigation

4. Vertical farming of transplants
- Shenandoah Growers

Vertical farming of transplants
- Battlefield Farms

Vertical farming of transplants
- Will it pay?
- Very approximate figures:
  - Scenario: 53 x 8 x 9 ft reefer trailer, carts, AC, LEDs, CO₂, 1200 square feet of shelf space
  - Capital cost $103,000 = $86/ft² of shelf
  - Operating & annualized costs = $40,000/year
  - Assume 54% average shelf space use
  - ≈ $1.20 per square foot per week
  - ≈ $2 per tray per week
  - ≈ $8 per tray for 4 weeks
Vertical farming of transplants

Tissue culture blueberries: Commercial greenhouse production

High % rooting crop

Low % rooting crop

Tissue culture blueberries grown for 4 weeks (pilot study)

Vertical farming – potential for profitability

- Reduced shrinkage
  - Extra production cost in VF compared with greenhouse
    - $8
  - Value of each rooted cutting
    - $0.50
  - Break even number of extra cuttings surviving per tray in VF
    - 16

Vertical farming – key questions

- It looks nice on paper… What is the reality?
  - Cost, scale, labor, & seasonality
  - High-valued crops
  - High shrinkage (is the answer VF or better growing & cutting quality?)

- Start with blueberry, & expand to other tissue culture crops
- Modular system for grower trials?
- We should be able to optimize the environment & learn physiology that can spin off into the greenhouse in the process

Example of physiology – what are the rate-limiting steps in propagation?

15h x 80 µmol/m²·s (~400 ft·c) = 4.3 moles/m²/day

15h x 150-260 µmol/m²·s (~750 to 1300 ft·c) = 8 to 14 moles/m²/day

Trends & Opportunities

1. Pre-rooted cuttings & direct sticking
   - We have a spreadsheet tool for your customized analysis
   - Need your help with enterprise budgets

2. Automation including cutting transplanting
   - We have a spreadsheet tool for your customized analysis
   - We are analyzing survey data & publishing articles

3. Optimize labor
   - Optimize manual process? Again, need enterprise budget for plugs, liners, finished
   - Let us know your training priorities

4. Vertical farming
   - Start with economic model & tc blueberry

Thank you for your support!

Growers

- Dumen Orange
- Four Star (MI)
- Knox Horticulture (FL)
- Kube-Pak (NJ)
- Lucas (NJ)
- Mast Young Plants/Neal Mast (MI)
- Pleasant View Gardens (NH)
- Rockwell Farms (NC)
- Speedling (FL, CA)
- Spring Meadow (MI)
- Vivero Internacional (Mexico)
- Walters Gardens (MI)

Allied

- AMA Horticulture
- Blackmore Co.
- Fine Americas
- GreenCare Fertilizers
- Griffin Greenhouse Supplies
- Klasmann-Deilmann
- Pindstrup
- Premier Tech Horticulture
- Quality Analytical Laboratories
- Sun Gro Horticulture

Erin Yafuso & Robyn Mucci