Pruning Studies to Manage Crop Load in Pennsylvania

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Outline

• Pruning for crop load potential: Getting crop “in the ballpark”
• Tall Spindle pruning severity studies: Gala and Fuji
• Artificial Spur Extinction: spur pruning Gala and Golden Delicious
Crop Load Terms

• Yield: Weight or volume (Bu) fruit / tree or / land unit (acre)
• Crop load: Fruit number per unit of bearing surface
  • trunk or limb size: No. / TCSA; No. / LCSA
  • Crop density
  • “Supply-Demand” ratio
Crop Load Mgt Options:

• Pruning: Adjust crop potential
• Blossom thinning
  • Chemical
  • Mechanical
• Post-bloom chemical thinning
  • Rescue chemical thinning at 20 mm
• Hand thinning: Corrective measure when all else fails
• Return bloom sprays
Pruning Goals: Fruit Size and Quality
Sunlight and Crop Density

• Pruning reduces yield and increases fruit size & quality
• Space fruiting laterals vertically & radially
• Reduce shading by reducing excess branching
• Reduce crop density to promote higher Leaf : Fruit ratio
• Can we quantify this?
Pruning for Peach Crop Load Goal
Quad V orchard

600 bushel / A of large (3”) fruit
    = 60,000 peaches per A
345 trees/A = 174 peaches/ tree
4 scaffolds / tree = 44 peaches/ scaffold
At 2 peaches per fruiting lateral = 22 laterals
Ballpark: Prune to 22 fruiting laterals / scaffold
Spurs & Terminals on 2+ Year Limbs

6 spurs / lcsa
Equilifruit Disk
Pruning for Apple Crop Load Goal:

1210 bushel / A of 3” fruit
  = 121,000 apples per A
1210 trees/A = 100 apples/ tree
100 apples @ 6 fruits / lcsa = 16.7 cm² lcsa per tree (2.6 in² lcsa)
If limbs are ~1 cm (0.4”) in diameter, 22/ tree are needed for a full crop
Estimated Limb No. for Target Yield / A  
1210 Trees / A (3’ x 12’ spacing)

<table>
<thead>
<tr>
<th>Yield Goal (Bu / A)</th>
<th>Fruit no. / tree</th>
<th>Limb csa / tree</th>
<th>Limbs / tree (est)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>83</td>
<td>14</td>
<td>18</td>
</tr>
<tr>
<td>1210</td>
<td>100</td>
<td>17</td>
<td>22</td>
</tr>
<tr>
<td>1500</td>
<td>124</td>
<td>21</td>
<td>27</td>
</tr>
<tr>
<td>1800</td>
<td>149</td>
<td>25</td>
<td>32</td>
</tr>
</tbody>
</table>
Pruning by the Numbers

Pruning Severity Treatments

Unpruned | LTR = 1.25 | LTR = 1.00 | LTR = 0.50

Remove a sequence of limbs, always removing the largest remaining limb until the level of severity meets the target value.
The Numbers?

• Need **measurable** benchmark
  1. To develop robotic pruning
     • What limbs to cut?
     • Threshold (when to stop?)
     • What & how much data needed?
  2. To evaluate: how did we do?
  3. Need for manual pruning too
Tall Spindle

- World standard
- Productive, quality
- Common canopy features
- Minimal branching
- One simple target
Severity: Limb - Trunk Ratio

- Measure diameter of each limb on 4 trees
- Measure the trunk diameter at 12 inches
- Calculate sum [LCSA] and TCSA.
- Choose desired LT ratio.
- Prune largest successive limbs to desired LT ratio.
Pruning Severity: Gala/ M.9
Number of limbs removed

\[ y = 7.43x^2 - 31.69x + 38.06 \]

\[ R^2 = 0.92 \]
Gala Yield per Tree

![Graph showing yield vs. pruning severity level (L:T)]

- Yield (kg per tree)
- Pruning severity level (L:T)
- 0.50, 0.75, 1.00, 1.25, 1.50, 1.75
Gala Fruit Size

![Bar chart showing Gala fruit size by pruning severity level (L:T). The x-axis represents pruning severity level (L:T) with values 0.50, 0.75, 1.00, 1.25, 1.50, and 1.75. The y-axis represents fruit size in g, ranging from 0 to 200. The chart shows a decrease in fruit size as the pruning severity level increases.]
Gala Crop Value
(2014 - 2015)

$\text{R}^2 = 0.6573$
Max remaining limb diameter after pruning

\[ y = -1.47x^2 + 7.69x + 5.05 \]
\[ R^2 = 0.86 \]
Severity: Max Limb Diameter

- Measure sum[LCSA] / tree and TCSA on ~4 representative trees
- Establish target severity (LT ratio)
- Regression to establish max remaining limb diameter (MD)
  - $MD \ (2013) = -0.87 + 0.553 \ TC + 4.29 \ LT$
- Then need only measure TC to determine the maximum allowable branch diameter from LT ratio data. Cut off all larger limbs.
MD: Maximum Allowable Branch Diameter
Fuji Pruning Severity Trial
Maximum remaining limb diameter after pruning, 4 year average

\[ y = -1.47x^2 + 7.69x + 5.05 \]

\[ R^2 = 0.86 \]
Cumulative average fruit size, 5 year

\[ R^2 = 0.51 \]
Fuji Fruit Size, 5 Year Average
Fuji Crop Value
Alternate bearing index

(Values closer to 1 indicate more alternate bearing. Values closer to 0 indicate less alternate bearing)
MD Method:

- Scan LCSA and TCSA in 4 trees / block
- Set desired severity level (LT)
  - 1.25 produced best yield / large fruit for Gala
- Calculate threshold diameter for largest remaining branch (MD)
  - 12.5 mm = ½ inch
- Prune off everything larger!
On-going Studies: MD Method for Pruning Severity

• LT ratio will change with tree age
  • After full canopy is achieved, does target LCSA become static?
  • TCSA will continue to increase
  • If so: calculate target LCSA per acre
  • Measure trunk of each tree to determine that tree’s share of LCSA.
MD Method

- Goal can be adjusted
  - Mgt. goals
  - Site capability
  - Cultivar, etc.

- Simple severity rule for engineers to design automated pruning
Pruning Rule Orders

1. Remove all >MD limbs with renewal cut
2. Remove all pendant / upright limbs
3. Thin out horizontal limbs to 8 per m
4. Prune each remaining limb to a single axis
Experimental Pocket Guide

Sequential Pruning Procedures

1. Remove all limbs > 1/2 inch diameter with renewal cut

2. Remove all pendant ("hangers") and upright limbs ("risers")

3. Thin out remaining limbs to 8 per 3 ft of leader length

4. Thin out secondary branches on each remaining limb to create a single axis

Orden de los Pasos para la Poda

1. Remover todas las ramas de más de 1.25 cm de diámetro con un corte de renovación

2. Remover todas las ramas colgantes (que crecen hacia abajo) o verticales

3. Entresacar la cantidad de ramas que quedan hasta 8 por cada 1 m de la altura del tronco

4. Entresacar las ramitas secundarias en cada rama que queda para formar un solo eje
Summary: Size Matters
• Goal: to do 70% pruning = 90% benefit
• We can reach this goal with one rule
Artificial Spur Extinction (ASE)

• Early season decrease in potential crop load
  • Branch level manipulation
  • Used widely in New Zealand and Australia
    • Followed with hand thinning

1. Early in the season excess fruiting buds (spurs) are removed
  • Around tight cluster or green tip
  • Standard: 6 buds per cm² limb cross sectional area (lcsa)

2. All lateral buds stripped from one year old wood
Previous Research on ASE

- Designed to mimic reproductive strategies of type IV apple trees
  - Developed in France
- Currently widely practiced in New Zealand and Australia
  - Examined impacts on multiple varieties
    - Preventing early bearing
    - Decreasing bienniality
    - Fruit quality and storability
  - Follow up hand thinning
PA Research on ASE

Pennsylvania: focused on implementation methods

- Traditional ASE using the Equili-fruit disc
- Estimated ASE
- ASE in combination with pruning to 6 limbs/m canopy
  - New Zealand
- Mechanical ASE using string thinner
Golden Delicious: Yield

![Bar chart showing average yield in kg for different treatments by year: 2015, 2016, 2017. The treatments include Control, ASE, ASE Est, P6 + ASE Est, and Mech ASE. The chart indicates variations in yield across these treatments and years.]
Golden Delicious: Fruit Size

Individual Fruit Weight (g)

- Control
- ASE
- ASE Est
- P6 + ASE Est
- Mech ASE
Golden Delicious: Conclusions and next steps

• No discernible trend
  • Fruit size and yield weren’t improved reliably by any treatment
• Standard (6 buds/cm² lcsa) is not low enough for Pennsylvania climates
• Determine if a level of spur extinction can produce ideal fruit size and quality in Pennsylvania Orchards
  • Achieving ideal crop load
  • Maximizing crop value
  • ‘Gala’
Artificial Spur Extinction: Intensity

• Mature ‘Crimson Gala’ apple trees
  • Trained to tall spindle
• Thinned in mid March
  • At or before green tip
  • 5 treatment groups
    • ASE2, ASE4, ASE6
    • Control A (removed laterals), Control B (intact laterals)
ASE 2  ASE 4  ASE 6  Control

(4 trees per treatment)
Two seasons of data
Environmental Variability

Hail event in 2018
- Petal fall
- Physical damage caused low fruit set
Yield Distribution:

- Individual Fruit Weight (g)
- 4 tree yield (kg)

Legend:
- Control B
- Control A
- ASE 6
- ASE 4
- ASE 2
Crop Value

- ASE2
- ASE4
- ASE6
- Control A
- Control B

Crop Value ($/tree)

- 2017
- 2018

Crop Value ($/tree) vs. Year
ASE Conclusions

• Current results
  • Not as promising as in the southern hemisphere
    • Lack of follow-up thinning?
    • Climate Differences
  • Risk associated with early thinning
  • Not recommended for Mid-Atlantic growers

Thank you
• State Horticultural Association of Pennsylvania
• Penn State FREC