Do High Density Apple Planting Systems Make Sense?

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What is an Orchard System?

An orchard system is a comprehensive program (a strategy and a recipe) for the establishment of trees in an orchard.

Barritt 2003
PROFIT GENERATORS

• PRODUCT PRICE
  – FRUIT QUALITY
    • VARIETY – Honeycrisp
    • FRUIT SIZE – Gala
    • FRUIT COLOR - McIntosh
    • FRUIT CONDITION – Empire
    • MARKET CONDITIONS – Macoun

• YIELD

• Precocity - TIME TO FIRST BEARING
• TIME TO MATURE YIELD
THE ORCHARD SYSTEMS PUZZLE

- ROOTSTOCK
- MANAGEMENT SKILLS
- VARIETY
- SPACING
- SITE
- TREE TRAINING
- SUPPORT SYSTEM
The Critical components of an Orchard System are those that are necessary to make the orchard Profitable!

A successful System will:

• Produces high yields of high quality fruit.
• Early return on capital (rapid production)
• Economizes on labor input
• Economizes on materials input?
Key Questions

- Does High Density really make economic sense?
- What Density and what system of pruning and training are best?
- How important is the Planting System?
- Does Tree Density or Training System Influence Fruit Quality?
- What other systems factors most strongly influence profitability?
There has been a steady evolution in planting systems.

- **1960’s**: 40 trees/acre
- **1980’s**: 200 trees/acre
- **1980’s**: Overgrown tops and shade

- **600 trees/acre**
- **Pedestrian Orchards**
There has been a steady evolution in planting systems.

**Triple Row Slender Spindle/M.9**

**Pedestrian Orchards-1980’s**

- Moderate yields and moderate light interception
- Higher yields but poor fruit quality in the center row and poor weed control

**Geneva Y-trellis/M.26**

- High yields and high light interception
Late 1980’s and early 1990’s- Tall Orchards (again)

USA-Vertical Axis - 500 trees/acre
Mid 1990’s - Super High Density  (2,200 tree/acre)

Super Spindle/M.9

V- Super Spindle/M.9
List of Planting Systems Trials

• Apple
  – Geneva (various planting dates)
  – Crist and Dressel – 1987       HV
  – Trapani and Clark - 1989       HV
  – LynOaken and Cahoon – 1989      WNY – Lake Ont.
  – Morgan and Lagoner - 1993&4    WNY – Lake Ont.
  – Dressel and Van de Walle – 2005 HV & WNY
  – Everett – 2006                 Champlain V
  – Chiaro – 2007                  HV
  – HVL – 2010                     HV
The Purpose of these Trials:

- A comparison of planting densities & systems, canopy architecture
- Develop an understanding of economic impact of various factors on profitability and cash flow
# Trapani/Clark Systems Trials

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<th>Spacing</th>
<th>Density (trees/a)</th>
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<td>Slender Spindle</td>
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<td>V-Slender Spindle (4X12)</td>
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Planting Systems

V Slender Sp

Triple Row

Slender Spindle

4 Wire Trellis

Y Trellis
# Orchard Dale Planting Systems Trial

(Planted 1993)

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<td>V-Slender Spindle/M.9</td>
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<td>V-Trellis /M.9</td>
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<tr>
<td>Super Spindle/M.9</td>
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Vertical Axis

Orchard Dale
2 Year Old Gala/M.9 trained to Super Spindle
# The Geneva Planting Systems Trial 1997

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<tr>
<td>Super Spindle</td>
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NYSAES

Super Spindle

Spindle
2.0 X 10 ft
10 ft tall

Tall Spindle

3.0 X 11 ft
11 ft tall
Which Planting System Was Best?

- Slender Spindle Types
- Multiple Row Systems
- Vertical Trellis
- Y or V Trellis Types
- Vertical Axe Types
Planting Systems Analysis

• Establishment Costs
• Overhead Costs
• Growing Costs
• Total Yield
• Packout

• including deductions for:
  • Marketing orders
  • Storage and packing charges
  • Sales Commissions
Table 3. Spreadsheet to determine Potential Profit for Vertical Axis system @ 622 trees/acre.

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<th>Income</th>
<th>Harvest</th>
<th>Labor</th>
<th>Machinery</th>
<th>Materials</th>
<th>Growing</th>
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<th>Harvest</th>
<th>Total Costs per Acre</th>
<th>Net Cash Flow</th>
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Internal Rate of Return: 8.74%
About the Analysis:

• Discounted Cash Flow = Time Value of $$
  – A dollar received today is worth more than a dollar received some time in the future
  – Internal Rate of Return
  – Net Present Value
    • If the NPV of accumulated profit reaches zero – it is a worth doing
Warning:

• We hope you see the forest from the trees
  – Overall concepts versus individual costs used in the example
  – Costs representative of Western NY fruit farms in transition from low density to higher density orchards
  – You can plug your own costs in later!
  – Analysis: Excel workbook template
Horticultural Results

- Tree density had a highly significant positive effect on yield. The cumulative yield of the highest tree density was 3X greater than the lowest density.
- Tree density had a highly significant effect on final trunk cross-sectional area. The highest planting density produced trees about 1/3 the size of the lowest planting density.
Horticultural Results - Yield

The cumulative yield of the highest tree density was 3X greater than the lowest density.
Effect of Tree Density on Tree Size

- The highest planting density produced trees about 1/3 the size of the lowest planting density.
Economic Study used average yields and estimated cash flows over 20 years

Yield Curves for 5 systems

20 Year Cash Flows
When profitability was calculated per unit land area with traditional fruit prices, profitability over 20 years increased with increasing tree density up to a density of 1,000 trees/acre (2,500 trees/ha).

When profitability was calculated per $10,000 invested then the optimum tree densities was about 850 trees/acre (2,100 trees/ha).
Annual Yield of 5 Systems

- Central Leader (340 tr/ac)
- Vertical Axis (622 tr/ac)
- Vertical Axis (908 tr/ac)
- Tall Spindle (1340 tr/ac)
- Super Spindle (2178 tr/ac)
Net Present Value ($)

Year

NPV for 5 Systems

- Central Leader (340 tr/ac)
- Vertical Axis (622 tr/ac)
- Vertical Axis (908 tr/ac)
- Tall Spindle (1340 tr/ac)
- Super Spindle (2178 tr/ac)
The Necessity of Being an Efficient Producer

- Fruit yield had a large effect on profitability. If yields were reduced by 10% then the low density Slender Pyramid system was barely profitable. If yields were reduced 20% then only the Slender Vertical Axis system was profitable.
- Reducing yield level reduced the optimum density slightly from 1,100 to 1,000 trees/acre.
- 10% yield reduction then the low density Slender Pyramid system was barely profitable.
- 20% yield reduction only the Slender Vertical Axis system was profitable.
- Reducing yield level barely reduced the optimum density. (100 trees/Acre)
Figure 7. Effect of land cost on profitability (Net Present Value after 20 years) of 5 orchard systems with different tree densities.
Effect of Fruit Price (Variety)

- Low prices ($4.50/bu) All systems are not profitable except the Slender Vertical Axis (900 trees/acre).

- Very High Prices ($10.00/bu) then profitability was greatest at the highest tree density (2178 trees/acre- Super Spindle).

- High fruit prices ($6.50) then profitability was high for all systems but peaked for Tall Spindle.
Effect of Fruit Price (Variety)

- Fruit price had the greatest effect on profitability.
- If fruit prices were low ($4.50/bu) then all systems were not profitable except the Slender Vertical Axis.
- If fruit prices were very high ($10.00/bu) such as with a new club variety then profitability was greatest at the highest tree density (2178 trees/acre - Super Spindle).
- At very high fruit prices profitability was extremely high for all systems.
Effect of Fruit Price on Profitability

- $5.50/bu Fruit Price
- $4.50/bu Fruit Price
- $6.50/bu Fruit Price

Net Present Value ($) vs. Trees Density (Trees/Acre)
• Low tree prices ($2.00/tree) the optimum density was above 2,000 trees/acre (Super Spindle).

• High tree prices ($8.00) the optimum density was between 950 trees/acre (Vertical Axis)

• At high planting densities tree price had a very large impact on profitability while at low tree densities tree price had only a small effect on profitability.
Tree price had a large influence on profitability and the optimum tree density. With low tree prices the optimum density was above 2,000 trees/acre (5,000 trees/ha) while with high tree prices the optimum density was between 950 trees/acre (2,300 tree/ha).

At high planting densities tree price had a very large impact on profitability while at low tree densities tree price had only a small effect on profitability.
Figure 9. Effect of tree price on profitability (Net Present Value after 20 years) of 5 orchard systems with different tree densities.
Profitability over 20 years increases with increasing tree density up to a density of 1,000 trees/acre (2,500 trees/ha).
Economic Considerations

• With high fruit prices optimum density is high >1,500 trees/acre.
• With moderate fruit prices optimum density is 1,000 trees/acre.
• With low fruit prices all systems are not profitable.
• Regardless of land cost or interest rate the optimum density is ~1,000 trees/acre.
Conclusions

1. All Planting Systems were profitable!
2. The Higher Density planting systems reached full production more quickly than lower densities.
3. Higher density orchards did not ultimately produce a higher yield per acre.
4. Quality was difficult to maintain on multiple row systems but not single row systems
Conclusions

• From the Processing Systems Trials:
  • The higher density systems produce much higher yields than the low density systems with all varieties.
  • The highest yielding varieties had 1.5 to 2 times the yield of the lowest yielding variety.
  • Better soils give significantly greater yield.
  • With peeler prices the breakeven year is likely to be much later (year 18-20) than with fresh fruit prices (year 10-13).
Economic Considerations

• Long term profitability is maximized by planting high tree densities.

• Optimum density depends on fruit price, tree price, land cost and establishment costs.
  • For Slender Pyramid, Vertical Axis, and Slender Axis the best quality trees are the most profitable even if the cost is high.
  • For Tall Spindle moderate tree prices are essential for profitability.
  • For Super Spindle low tree prices are essential for profitability.

• At the very high planting densities the cost per tree has a large impact on profitability.

• The greater the investment in a new orchard the greater the risk, thus higher tree densities usually bring higher risk.
Economic Considerations

- We believe the best combination of high profitability without excessive risk is achieved by:
  - The Tall Spindle (3-4' X 11 X 12') for fresh fruit blocks. This gives a tree density range of 907-1320 trees/acre.
  - The Vertical Axis (5-6' X 14') for low priced apple or processing blocks. This gives a tree density range of 518-622 trees/acre.
Our Systems Trials have shown the most successful plantings have:

1. Planting densities of 800 – 1000 tree/acre
2. Size controlling and precocious Rootstocks - preferably an appropriate clone of M.9, B.9 or a Geneva stock (G.11, G935, G.41).
3. Are planted in Single rows
4. Use high quality large feathered nursery stock.
Our Systems Trials have shown the most successful plantings use:

5. Trees are supported to 10 feet in height
6. Are minimally pruned and appropriately trained.
7. Are managed for a balance of growth and fruiting.
8. Pest are managed for minimal effect on trees and fruit.
Vertical Axis vs. Tall Spindle Similarities?

- Early Fruiting and Yields
- High Quality Fruit
- High Mature Yields
- Labor Efficiency
Vertical Axis vs. Tall Spindle Differences?

- Density/Spacing
  - VA - High
  - TS – Higher

- Nursery Tree required
  - VA - Better
  - TS – Best

- Training/Pruning
  - VA - Pinching
  - TS - Tying/Weighting

- Support System
  - VA – Post/Wire/Stakes
  - TS – Post/Wire/Support

- Rootstock?
  - VA – Full Dwarf?
  - TS – Full Dwarf
Components – Vertical Axis Density

• High Density
  – 500-700 trees/acre arranged in single rows.
  – Between row spacing of 12-14 feet
  – In-row tree spacing of 5-7 feet
  – Tree height of 11-12 feet with a narrow canopy width along the axis of only 3-5 feet
Components – Tall Spindle Density

- Higher density
  - 1000 – 1500 trees per acre.
  - The optimum average spacing for Tall Spindle is 3 X 11 ft
  - Maximum of 12 feet between rows.
  - The maximum in-row spacing is 4 feet
  - Proper selection of density for any system depends on consideration of the vigor of the variety and rootstock and the soil strength
Components – VA
Rootstock

- Best with vigorous clones of full dwarf rootstocks, M.9 Nic29, or B.9
- Dwarf Geneva rootstocks especially where fireblight is a problem (G.11, G.41, G.935)
- M.26 for very weak varieties
Essential Components – TS Rootstock

- Full dwarfing rootstocks –
  - The most successful Tall Spindle orchards established to date have been on M.9 and B.9. Precocious dwarfing stocks are important since early cropping is essential.
  - The yield efficiency and precocity of the Geneva rootstock series justifies their use especially where fireblight is a concern. Geneva 41, and G.11, are appropriate rootstocks for the Tall Spindle.
  - More vigorous rootstocks especially G.935 should only be used with the weakest growing varieties such as Spur Delicious and Honeycrisp.
Components – VA Nursery Stock

- Excellent feathered nursery tree
  - Trees with scaffolds provide bearing surface for early production.
  
  - Some transplant shock caused by a high top to root ration helps keep trees within this tight spacing. It also contributes to significant early fruit bud differentiation the year of planting.

  - Early bearing is essential to help pay for increased tree numbers and establishment costs.
Essential Component – TS Nursery Stock

• Highly feathered nursery trees
  – Nursery trees ideally have from 10-15 feathers per tree.
  – Trees with scaffolds provide bearing surface for production in the second leaf.
  – Transplant shock caused by a high top to root ration helps keep trees within this tight spacing. It also contributes to significant fruit bud differentiation the year of planting.
  – Early bearing is essential to help pay for increased tree numbers and establishment costs.
Essential Components – TS Yield

- Early Fruiting
  - Fruiting in the second and third leaf is essential to keep a low tree vigor level and provide income from early fruit sales.
  - Crops in the early years must also be carefully managed to prevent biennial bearing.
  - Aggressive pest management practices are essential starting in the second year since marketable crops are expected and necessary for optimum profitability.
  - This is the only system we have ever tested that achieved a cumulative production over 1000 bushels in the 1st five years, resulting in approximately a 40% increase in crop value compared to the Slender Vertical Axis and Sol Axis planting systems.
Gala, G.11, 2\textsuperscript{nd} leaf
2007
Essential Components – VA Support Systems

- Full Support System
- 10 ft in height
- High Wire with individual tree stakes
Essential Components – TS Support System

- Full Support System
- 10 ft in height
- Tall inline support posts (12 ft) and multiple wires. Training wires or stakes ideal
Components – VA
Pruning and Training

• Tip leader and side branches at planting to provide balance between the top and root and to encourage growth.

• Select leader

• Pinch new shoots along top ½ of the leader 1-3 times
Essential Components – TS
Pruning and Training

- Minimal pruning at planting
  - The Tall Spindle system is planted in place! Very little growth needed to fill the available space, therefore very little pruning is needed.

- Pruning is limited to only the removal of a few larger branches along the leader. Generally, those that are more than ½ the diameter of the leader at the insertion point are removed

- An important objectives is to actually cause some transplant shock..
Essential Components – TS
Pruning and Training

• Branch devigoration
  • 1<sup>st</sup> leaf
  • Upright scaffold branches are devigorated by bending below the horizontal through bending.
  • Use branch weights, rubber bands, or tying
  • Branch bending maintains vigor, keeps trees within allotted space, and encourages the production of fruit buds for the following growing season.
Combination of Tree weights and fruit
Components – VA
Pruning and Training

• Permanent bottom tier scaffolds
• Renewable above bottom tier
• Proper top management essential
Essential Components – TS
Pruning and Training

• Limb renewal
  • ALL scaffolds are renewed by complete removal as they become too large for the available space and become out of balance within the tree.
  
  • Renewal cuts are made using the standard method of using a “bevel cut” which encourages new shoots to form as replacement fruiting limbs.
  
  • There are no permanent limbs within the tree.
Leader Replacement