2012 Grand Traverse Orchard & Vineyard Show
January 24, 2012

Do High Density Apple Planting Systems Make Sense?

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What is an Orchard System?

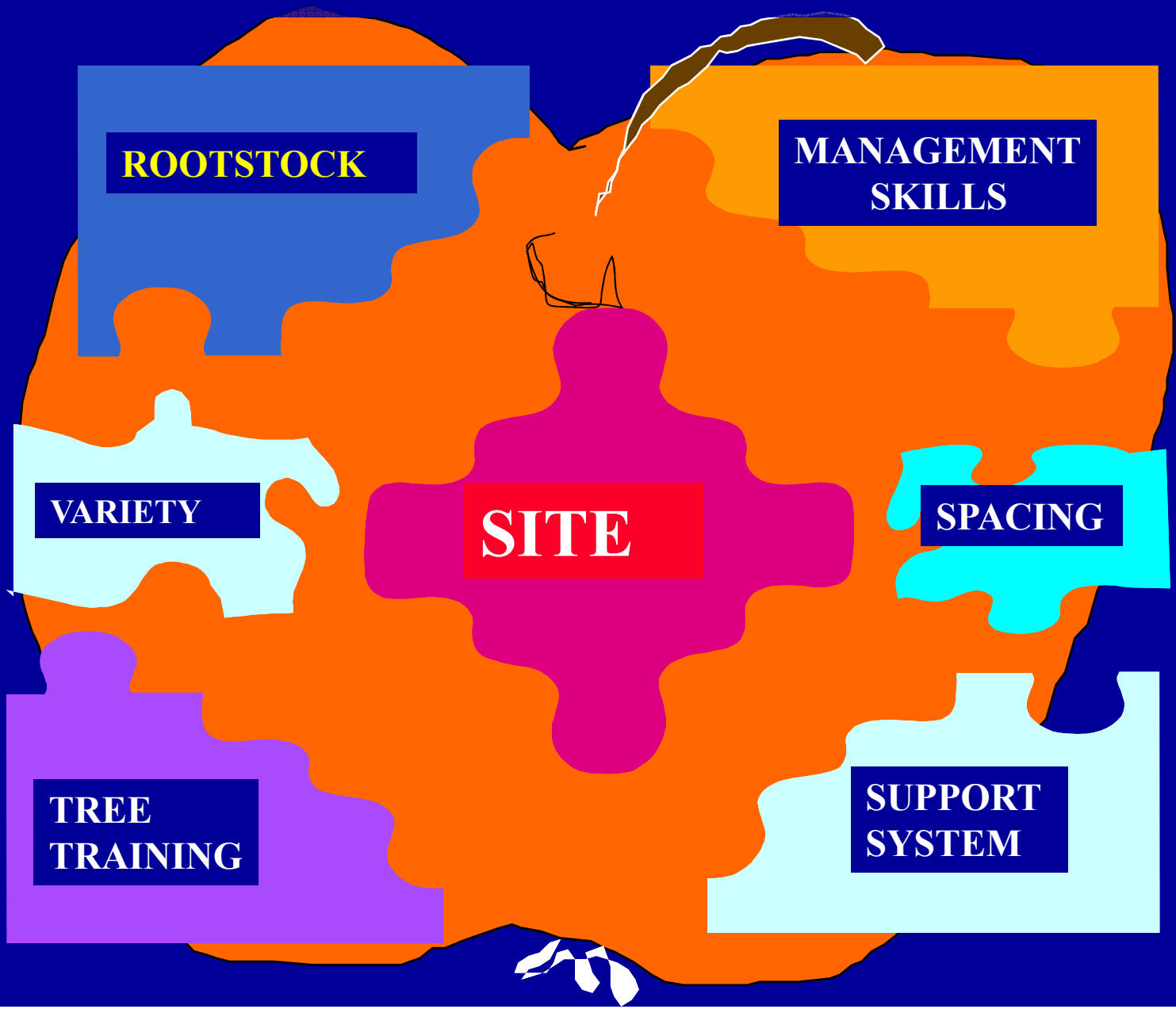
An orchard system is a comprehensive program (a strategy and a recipe) for the establishment of trees in an orchard.

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



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

40 trees/acre

1960's

200 trees/acre

600 trees/acre

Pedestrian

Orchards

1980's

Overgrown tops and shade

There has been a steady evolution in planting systems

Pedestrian Orchards-1980's

Moderate yields and moderate light interception

Triple Row Slender Spindle/M.9

Higher yields but poor fruit quality in the center row and poor weed control

High yields and high light interception

Geneva Y-trellis/M.26

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.
  - Orchard Dale - 1992 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

System	Spacing	Density (trees/a)
Vertical Axis/Mark	7X14	444
Vertical Axis/M.9/MM.111	7X14	444
Vertical Axis/M.26	8X16	340
Vertical Axis/M.7	8X16	340
Central Leader/Mark	10X18	242
Central Leader/M.9/MM.111	10X18	242
Central Leader/M.26	12X20	182
Central Leader/M.7	12X20	182

Cahoon and LynOaken Planting Systems Trial

System	Density	Type
4-Wire Vertical Trellis	605 T/A	Vertical
Slender Spindle	605 T/A	Vertical
Y-Trellis	605 T/A	V-shaped
Triple Row (6X6X12)	908 T/A	Vertical
V-Slender Spindle (4X12)	908 T/A	V-shaped

Planting Systems


V Slender Sp


Triple Row


Slender Spindle


4 Wire Trellis


Y Trellis

Orchard Dale Planting Systems Trial

(Planted 1993)

System	Trees/Acre
Slender Spindle/M.9	640
Vertical Axis/M.26	726
Vertical Axis/M.9	907
V-Slender Spindle/M.9	907
Y-Trellis /M.9	907
V-Trellis /M.9	907
Super Spindle/M.9	2420

Vertical Axis

Orchard Dale

2 Year Old Gala/M.9 trained to Super Spindle

The Geneva Planting Systems Trial 1997

System	trees/acre
Slender Pyramid/M.7	242
Slender Pyramid/M.26	340
Vertical Axis/M.9	414
Vertical Axis/M.9	518
High Density Vertical Axis/M.9	670
High Density Vertical Axis/M.9	908
Tall Spindle/M.9	1320
Super Spindle	2178

NYSAES

Super Spindle

Tall Spindle

Spindle
2.0 X 10 ft
10 ft tall

3.0 X 11 ft
11 ft tall

Recent Hudson Valley Trials
Chiaro, Crist

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.

2003 Planting System Analysis					Variety: **Gala**						Workbook by A. De Marree,		
Discount Interest Rate:			**5.0%**		Space between rows:	14					Cornell Cooperative Extension		
Cost to harvest a bushel of apples:			$1.11		Space between trees:	5					**Av. return per bu.**		**$5.50**
Value of land per ACRE:			**$1,000**										
Year	Yield kg/tree	Yield Bu. / A.	**Gross Income**	Labor	Machinery	Materials	Total Growing Costs	Total Fixed Costs	Total Harvest Costs	**Total Costs per Acre**	Net Annual Cash Flow	Annual N.P.V. Profit	**Accum. N.P.V. of Profit**
Land							1,000			**$1,000**	(1,000)	(1,000)	**($1,000)**
Preplant				111	845	339	1,295	537	0	**$1,832**	(1,832)	(1,832)	**($2,832)**
Planting	0.0	0.0	**$0**	790	658	5,527	6,975	537	0	**$7,512**	(7,512)	(7,154)	**($9,986)**
2	0.5	16.3	**$90**	448	205	302	955	537	18	**$1,510**	(1,420)	(1,288)	**($11,275)**
3	5.9	192.2	**$1,057**	537	205	555	1,298	537	213	**$2,048**	(991)	(856)	**($12,130)**
4	10.5	342.1	**$1,882**	794	205	562	1,560	537	380	**$2,477**	(596)	(490)	**($12,620)**
5	16.5	537.6	**$2,957**	621	205	389	1,216	537	597	**$2,349**	607	476	**($12,144)**
6	20.0	651.6	**$3,584**	615	205	376	1,196	537	724	**$2,456**	1,127	841	**($11,303)**
7	24.0	781.9	**$4,301**	620	205	501	1,327	537	868	**$2,732**	1,569	1,115	**($10,188)**
8	28.0	912.3	**$5,017**	611	205	564	1,380	537	1,013	**$2,930**	2,087	1,413	**($8,776)**
9	30.0	977.4	**$5,376**	617	205	521	1,344	537	1,085	**$2,966**	2,410	1,553	**($7,222)**
10	30.0	977.4	**$5,376**	620	205	536	1,361	537	1,085	**$2,984**	2,392	1,469	**($5,754)**
11	30.0	977.4	**$5,376**	620	205	536	1,361	537	1,085	**$2,983**	2,392	1,399	**($4,355)**
12	30.0	977.4	**$5,376**	620	205	536	1,361	537	1,085	**$2,983**	2,392	1,332	**($3,023)**
13	30.0	977.4	**$5,376**	620	205	536	1,361	537	1,085	**$2,983**	2,392	1,269	**($1,754)**
14	30.0	977.4	**$5,376**	620	205	536	1,361	537	1,085	**$2,983**	2,392	1,208	**($546)**
15	30.0	977.4	**$5,376**	620	205	536	1,361	537	1,085	**$2,983**	2,392	1,151	**$605**
16	30.0	977.4	**$5,376**	620	205	536	1,361	537	1,085	**$2,983**	2,392	1,096	**$1,701**
17	30.0	977.4	**$5,376**	620	205	536	1,361	537	1,085	**$2,983**	2,392	1,044	**$2,744**
18	30.0	977.4	**$5,376**	620	205	536	1,361	537	1,085	**$2,983**	2,392	994	**$3,738**
19	30.0	977.4	**$5,376**	620	205	536	1,361	537	1,085	**$2,983**	2,392	947	**$4,685**
20	30.0	977.4	**$5,376**	620	205	536	1,361	537	1,085	**$2,983**	2,392	902	**$5,587**
											1,000	377	**$5,964**
										Internal Rate of Return:			**8.74%**

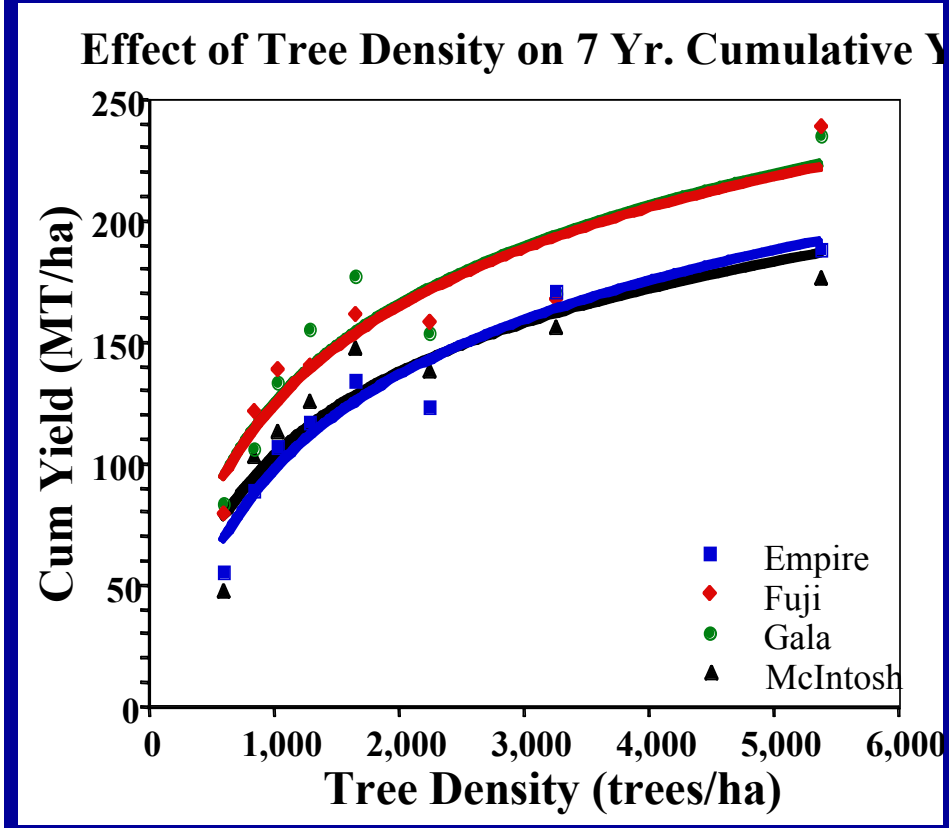
About the Analysis:

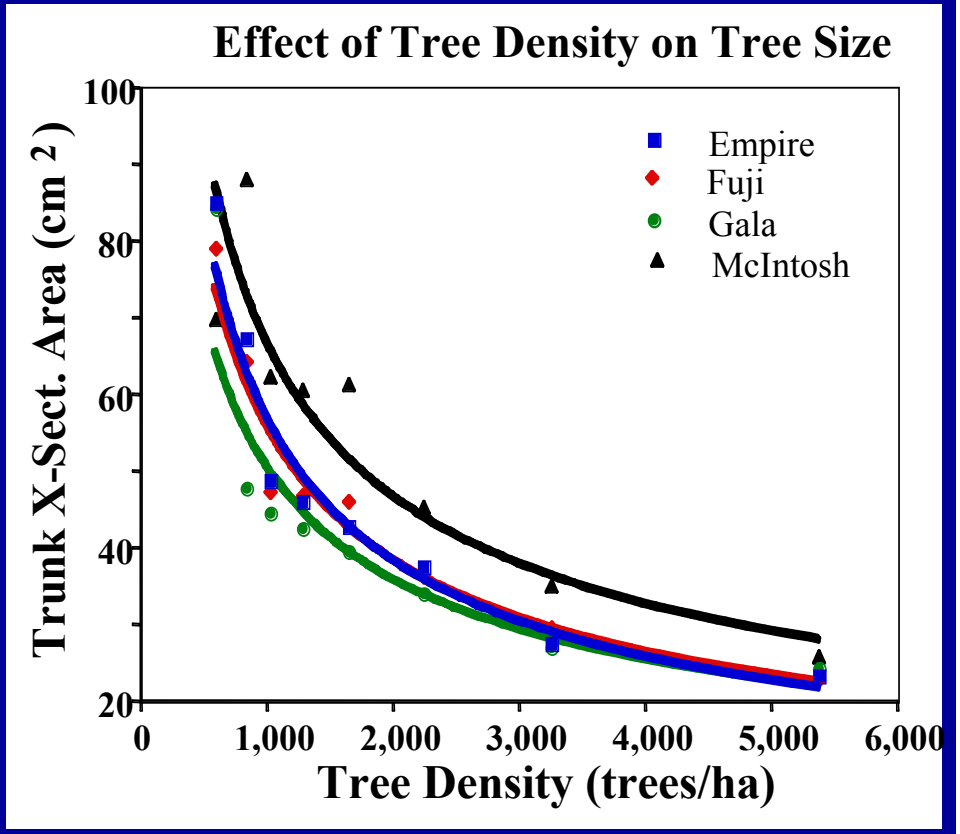
- Discounted Cash Flow = Time Value of $$
  - A dollar received today is worth more than a dollar received some time in the future
  - Internal Rate of Return
  - Net Present Value
    - If the NPV of accumulated profit reaches zero – it is a worth doing

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

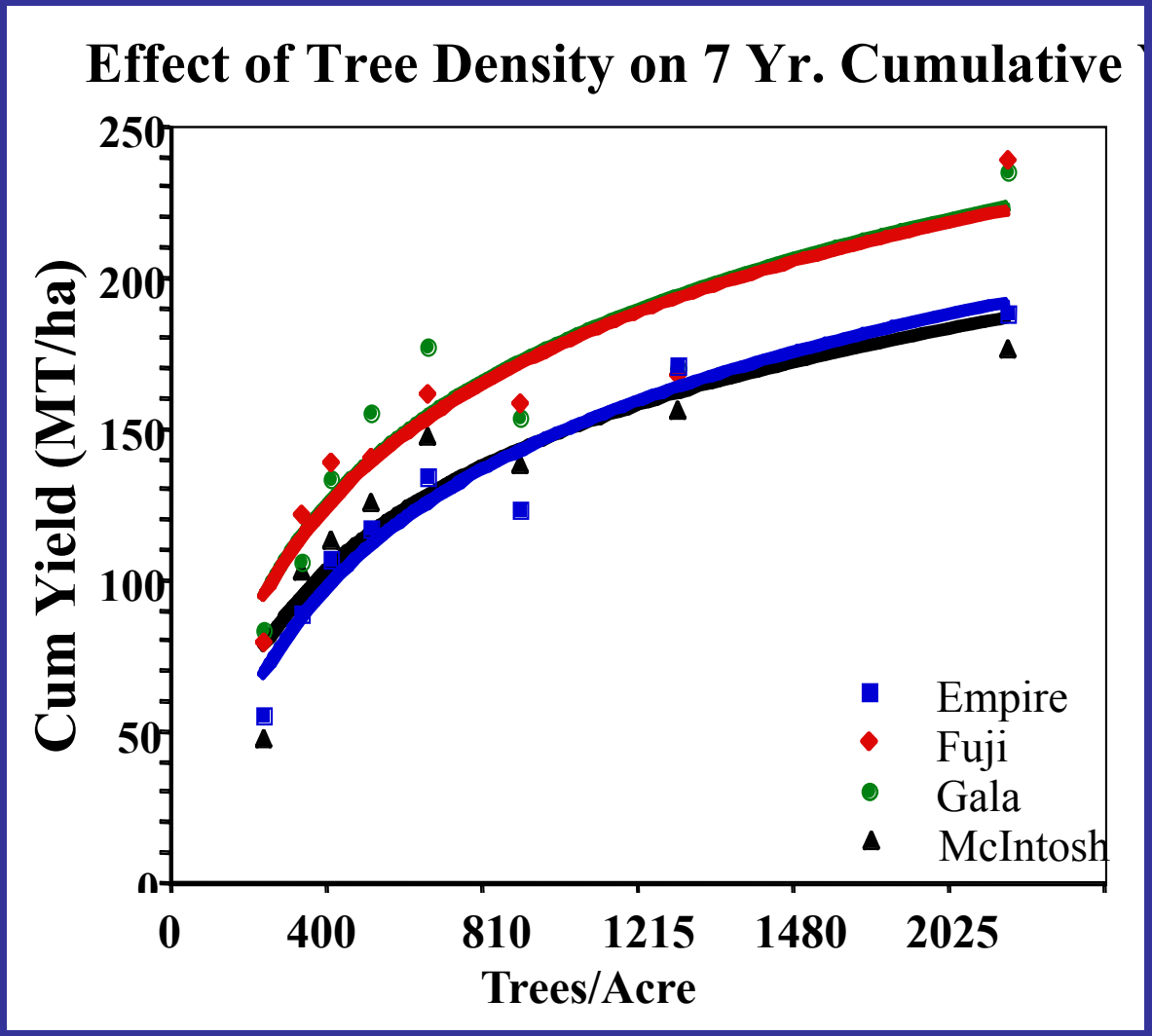
Horticultural Results





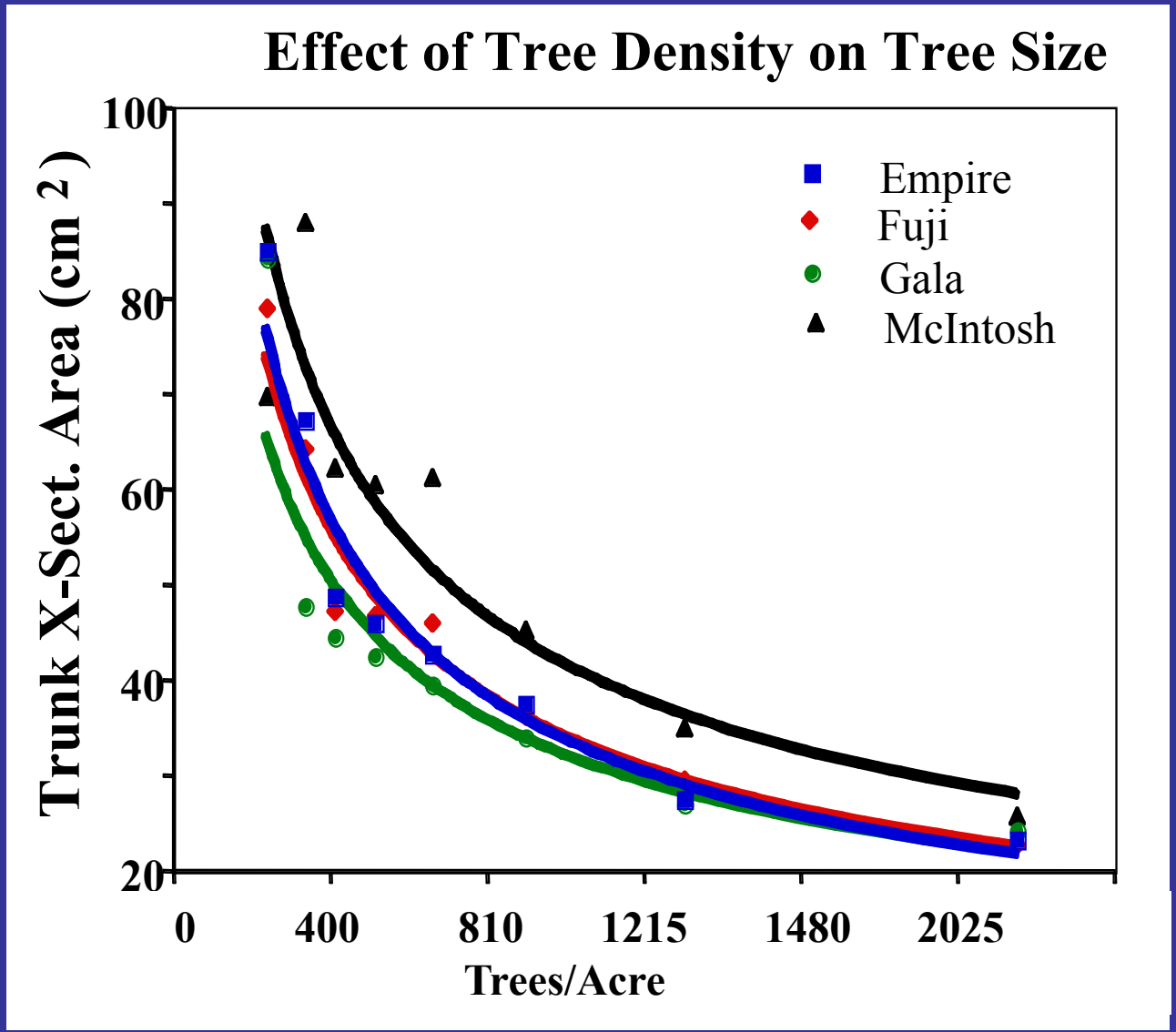
- Tree density had a highly significant positive effect on yield. The cumulative yield of the highest tree density was 3X greater than the lowest density.
- Tree density had a highly significant effect on final trunk cross-sectional area. The highest planting density produced trees about 1/3 the size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

Horticultural Results - Yield



The cumulative yield of the highest tree density was 3X greater than the lowest density.

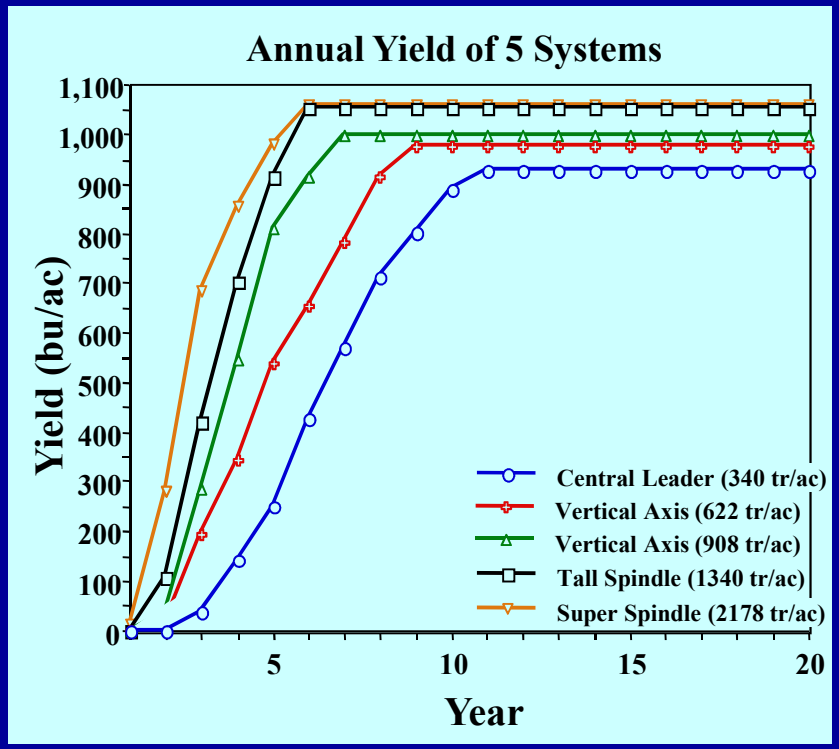
Horticultural Results - Tree Size



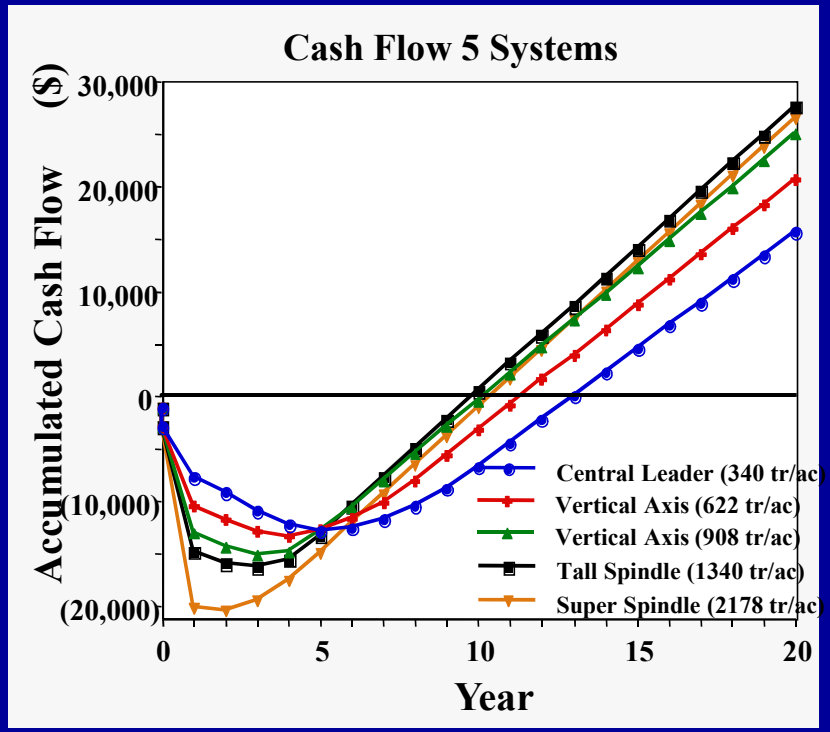
- The highest planting density produced trees about 1/3 the size of the lowest planting density.

Economic Study used average yields and estimated cash flows over 20 years

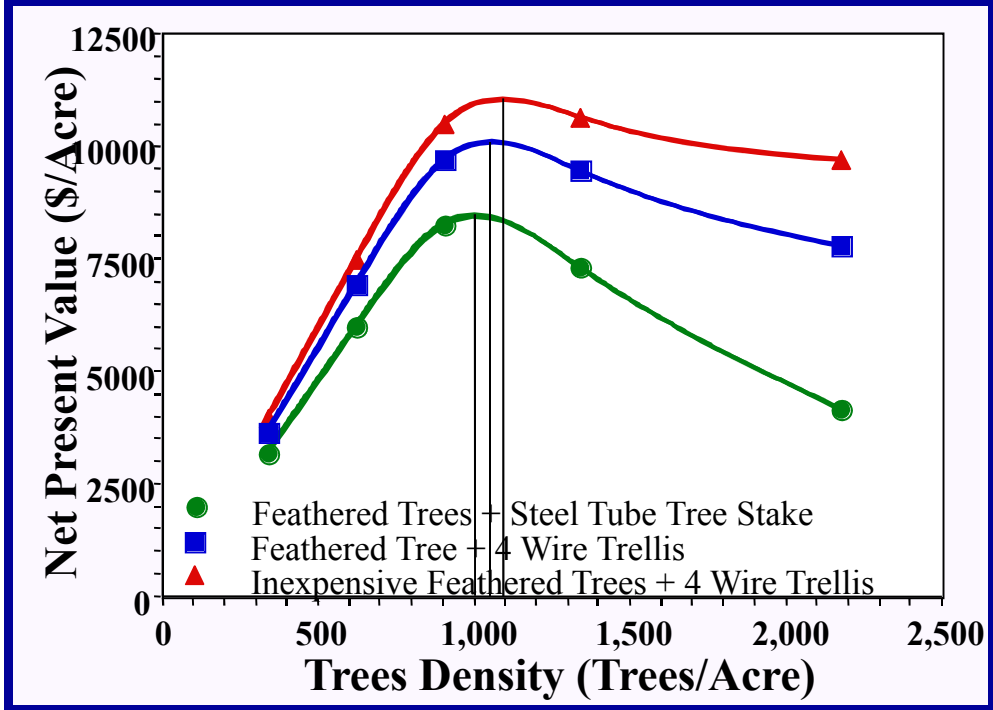
Yield Curves for 5 systems

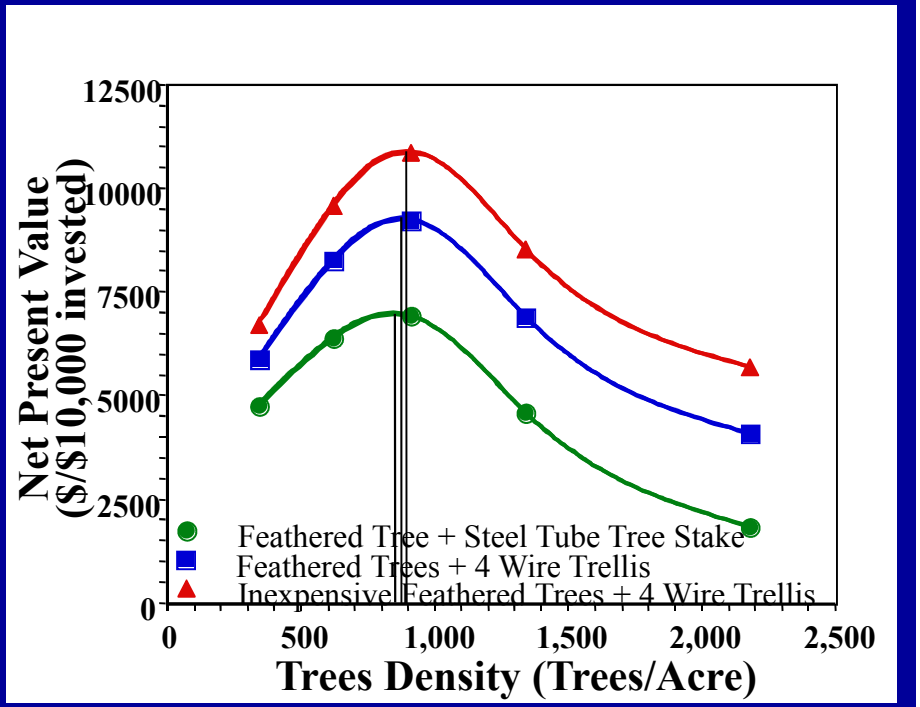


20 Year Cash Flows



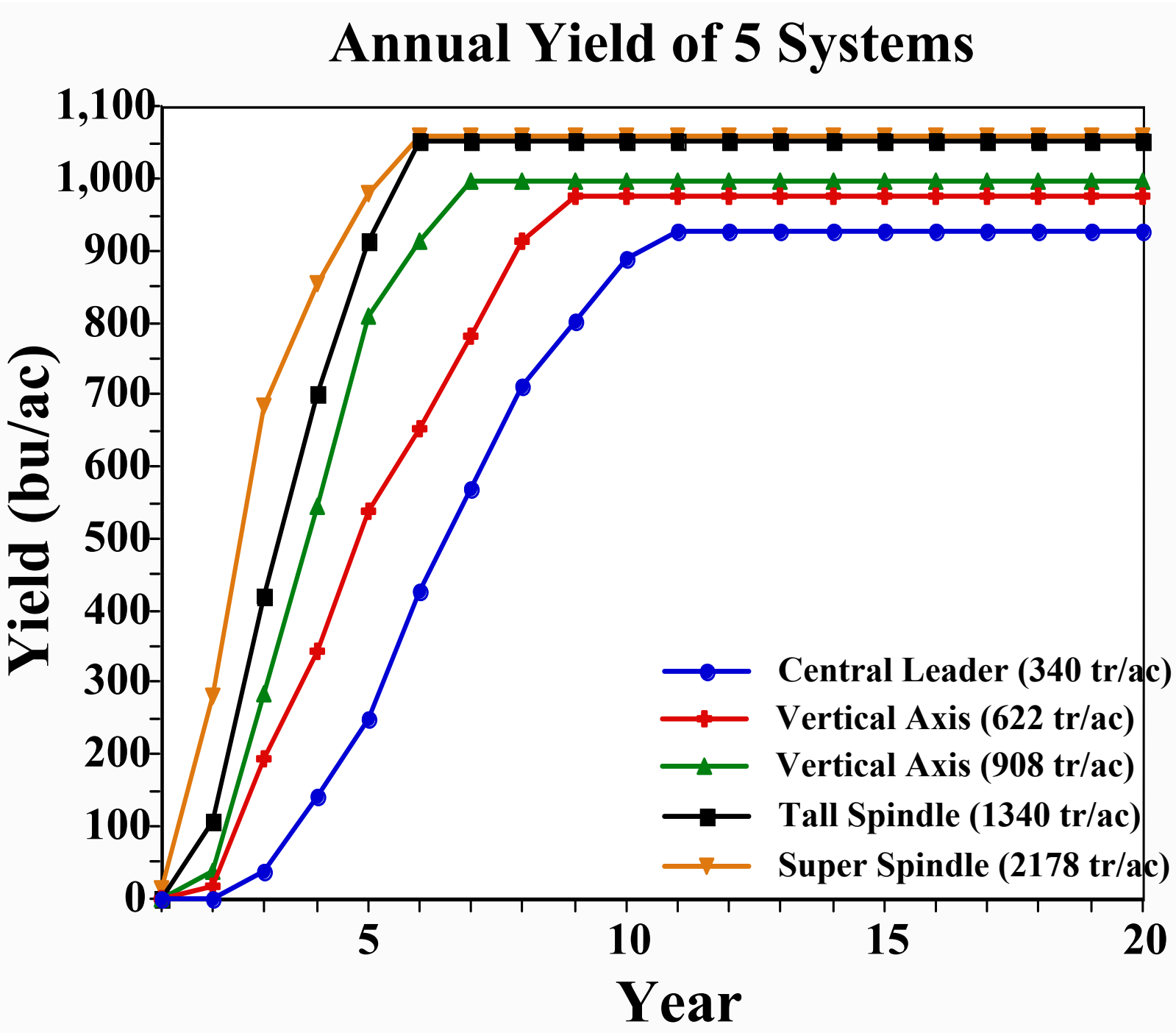
Economic Results

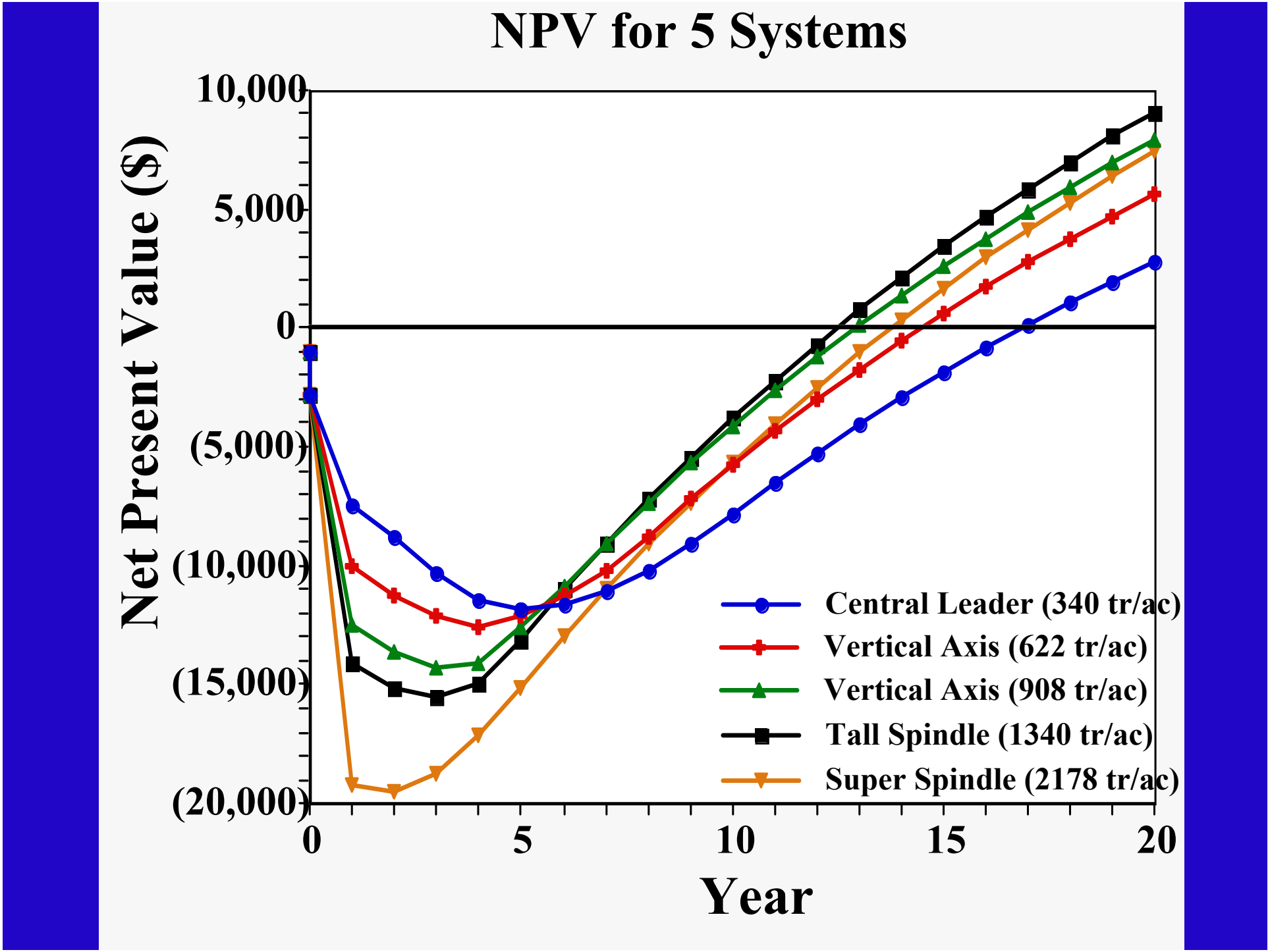




When profitability was calculated per unit land area with traditional fruit prices, profitability over 20 years increased with increasing tree density up to a density of 1,000 trees/acre (2,500 trees/ha).

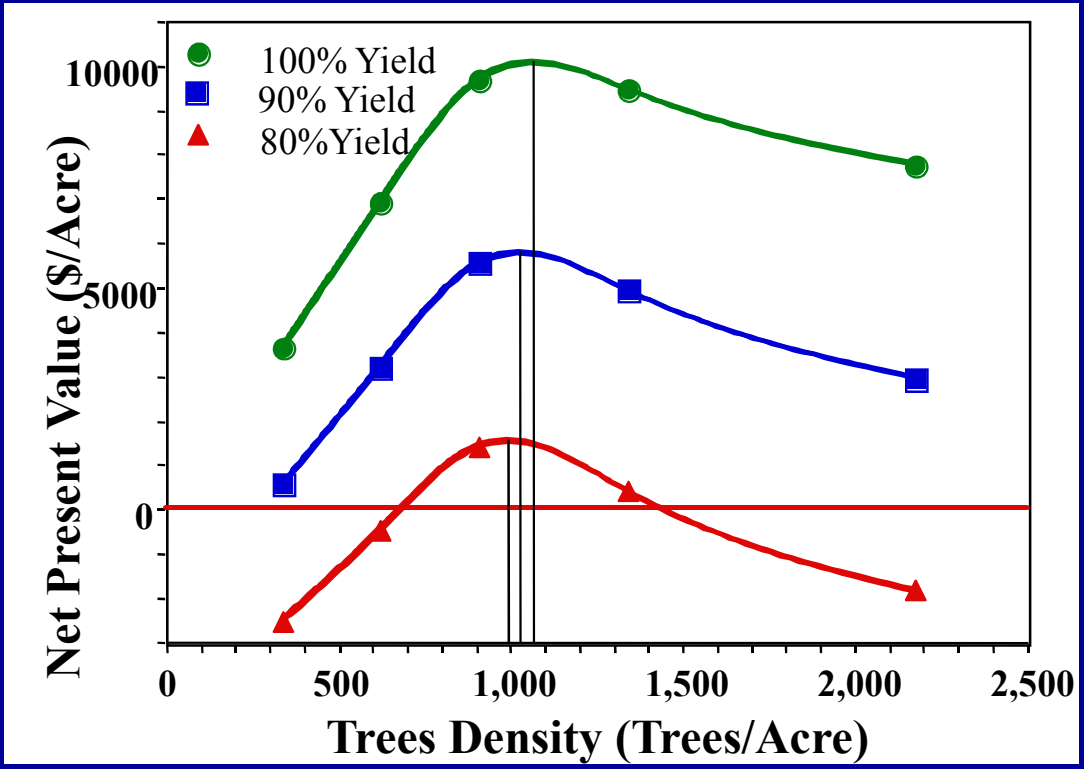
When profitability was calculated per $10,000 invested then the optimum tree densities was about 850 trees/acre (2100 trees/ha).


Annual Yield of 5 Systems
Yield (bu/ac)
1,100
1,000
900
800
700
600
500
400
300
200
100
0
5
10
15
20
Year
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)

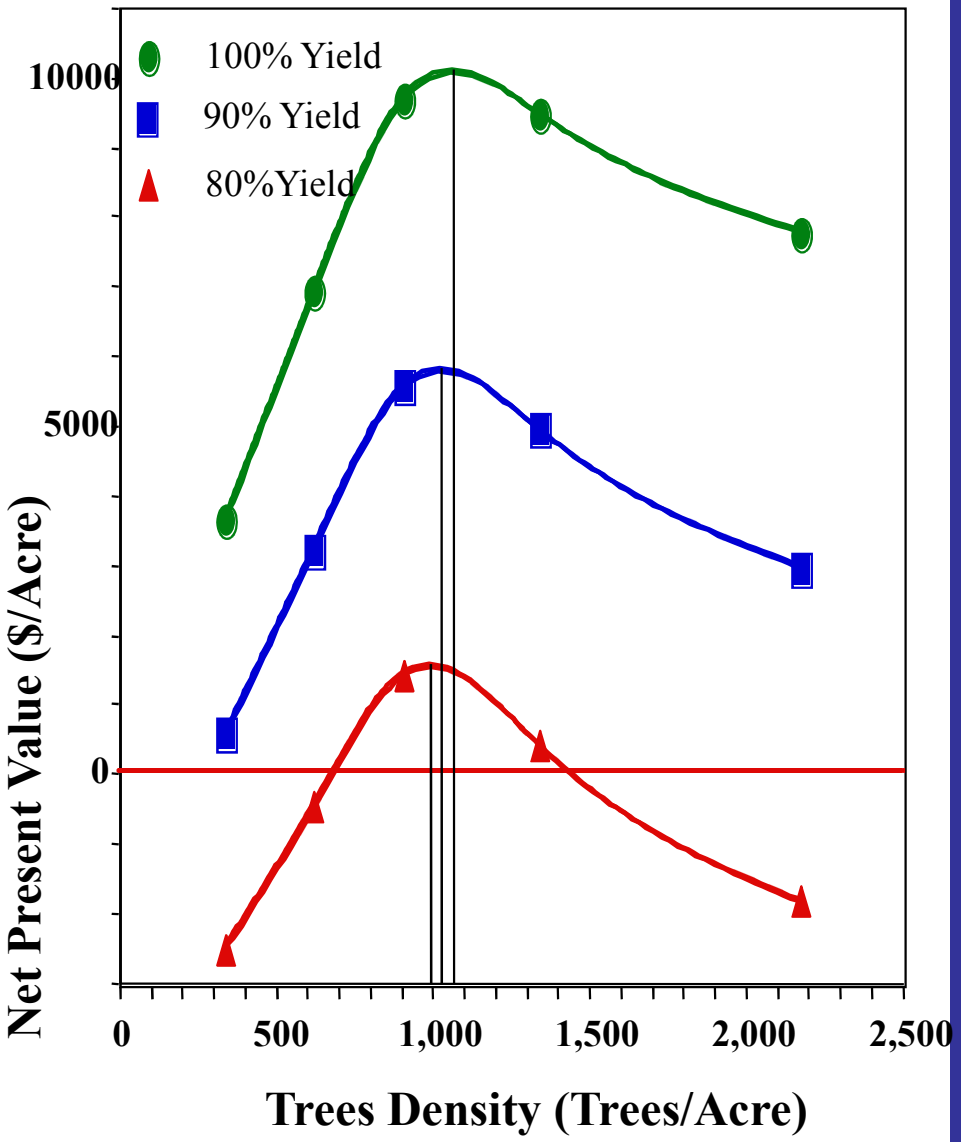

NPV for 5 Systems
Net Present Value ($)
10,000
5,000
0
(5,000)
(10,000)
(15,000)
(20,000)
0
5
10
15
20
Year
Central Leader (340 tr/ac)
Vertical Axis (622 tr/ac)
Vertical Axis (908 tr/ac)
Tall Spindle (1340 tr/ac)
Super Spindle (2178 tr/ac)

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.



High Yields



- 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)

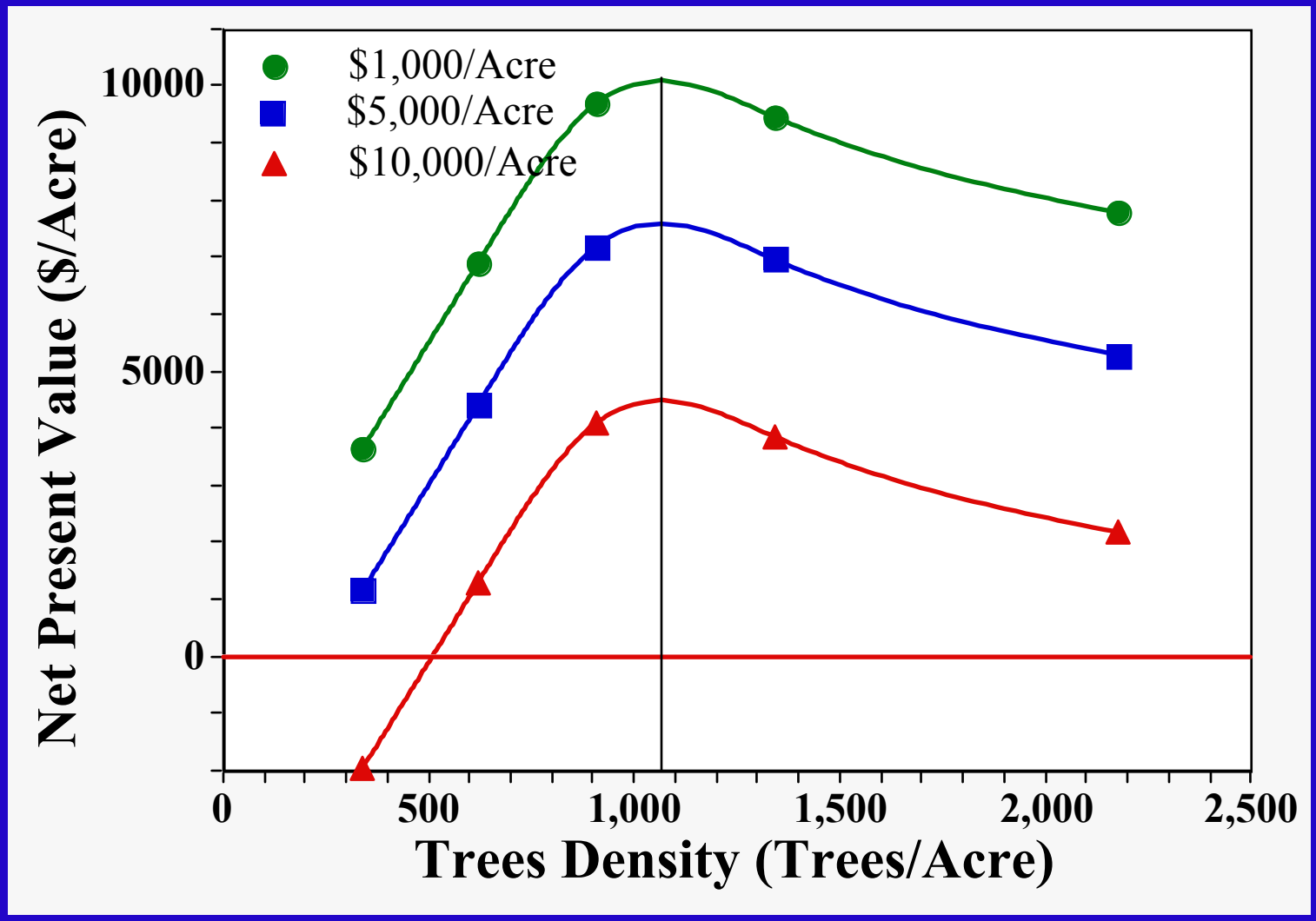
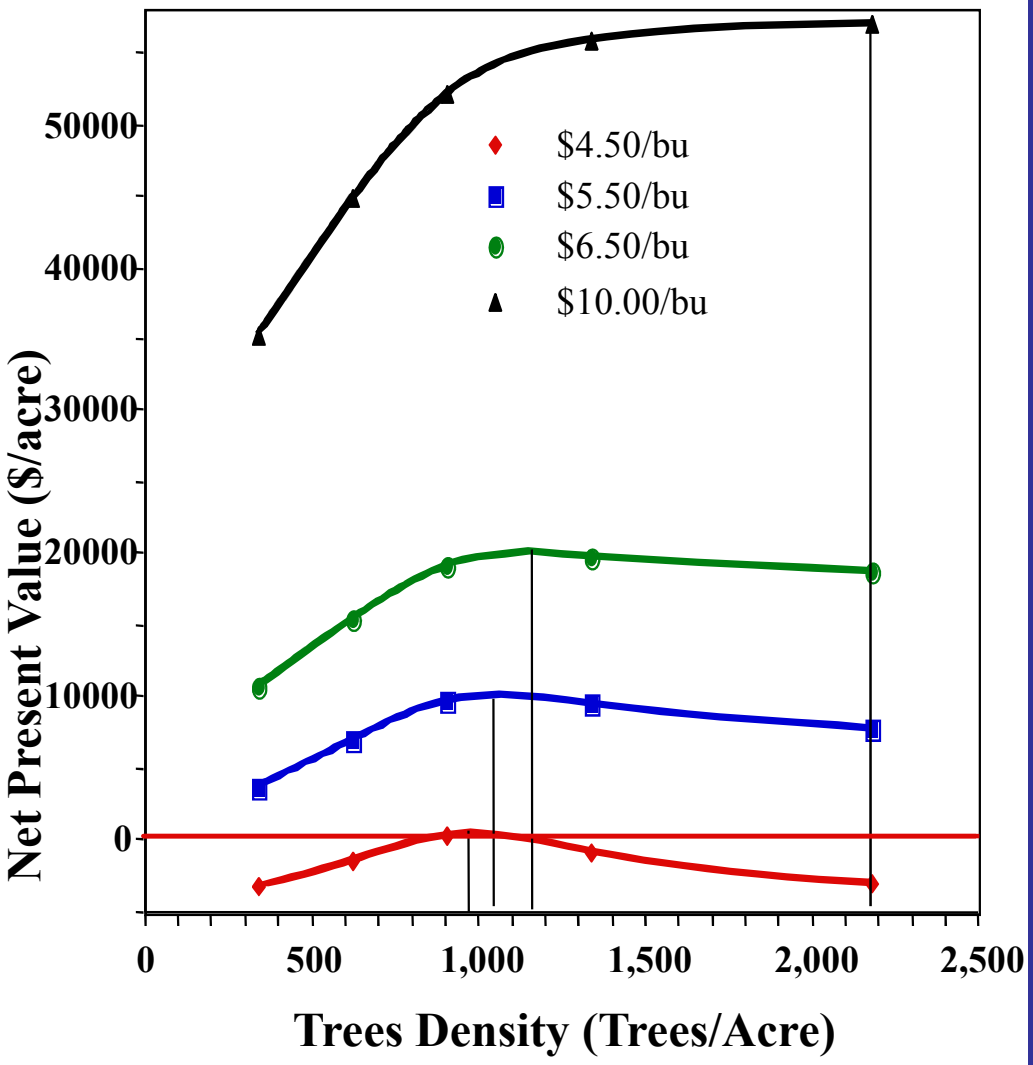


Figure 7. Effect of land cost on profitability (Net Present Value after 20 years) of 5 orchard systems with different tree densities.

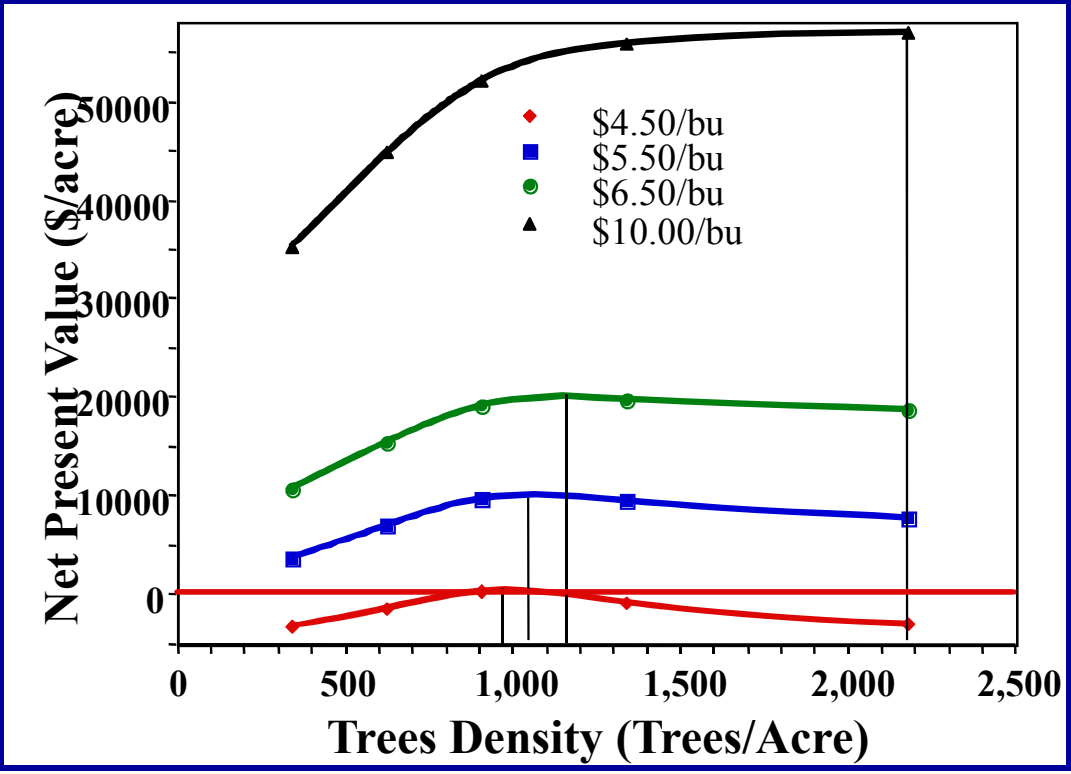
Effect of Fruit Price (Variety)



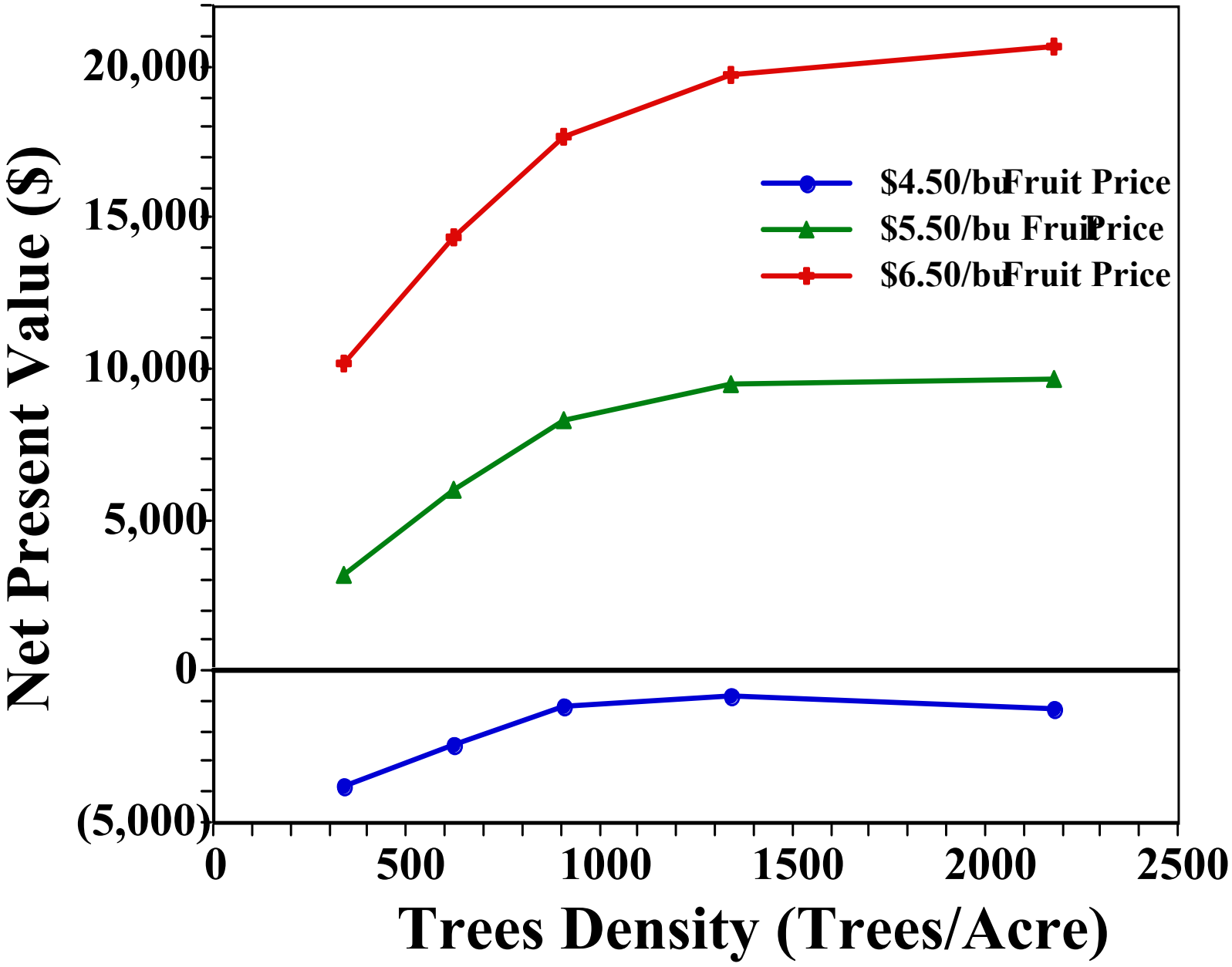
- Low prices($4.50/bu) All systems are not profitable except the Slender Vertical Axis (900 trees/acre).
- Very High Prices ($10.00/bu) then profitability was greatest at the highest tree density (2178 trees/acre- Super Spindle).
- High fruit prices ($6.50) then profitability was high for all systems but peaked for Tall Spindle.

Effect of Fruit Price (Variety)

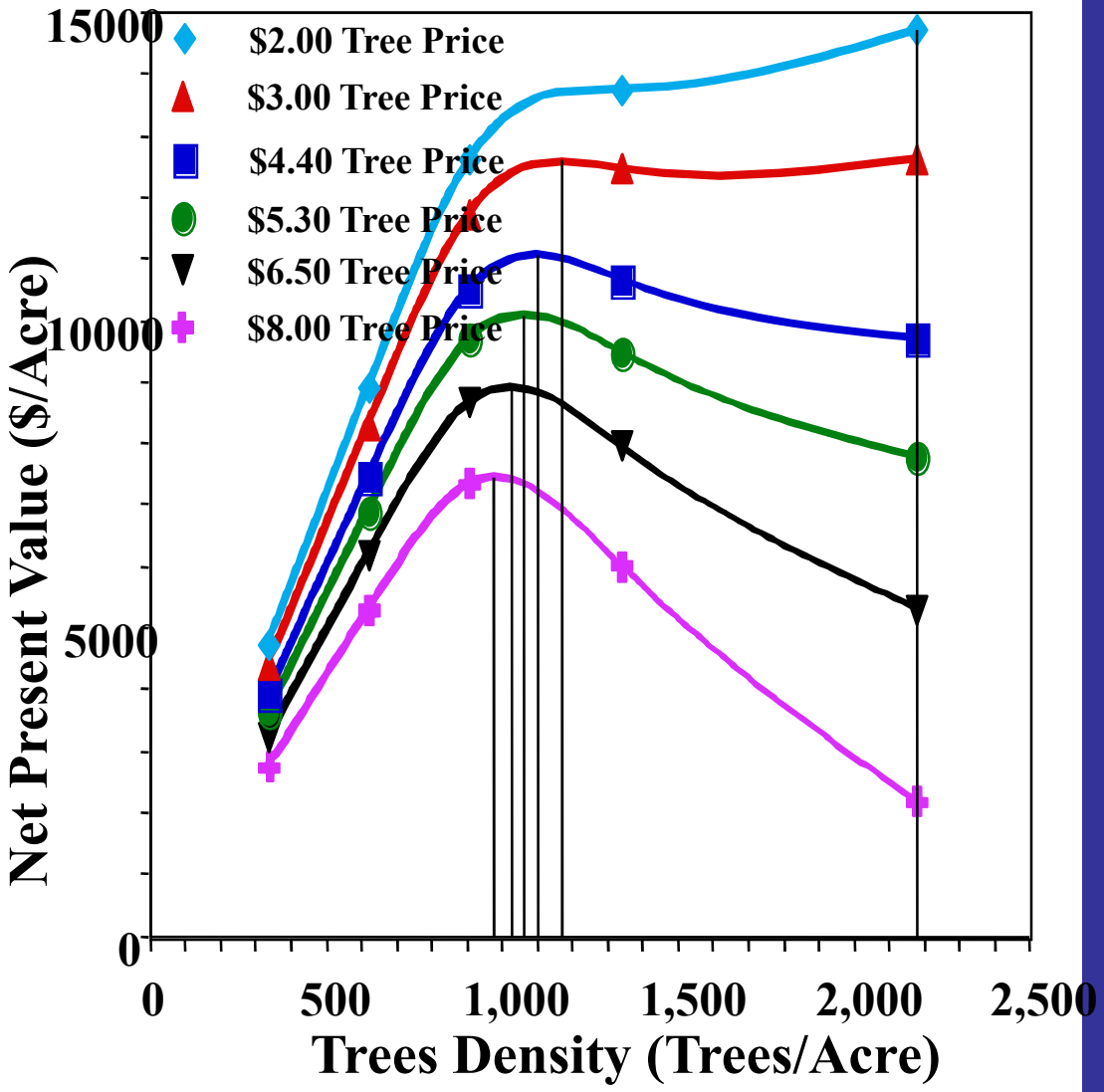
- Fruit price had the greatest effect on profitability.
- If fruit prices were low ($4.50/bu) then all systems were not profitable except the Slender Vertical Axis.
- If fruit prices were very high ($10.00/bu) such as with a new club variety then profitability was greatest at the highest tree density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



Effect of Fruit Price on Profitability



Tree Price

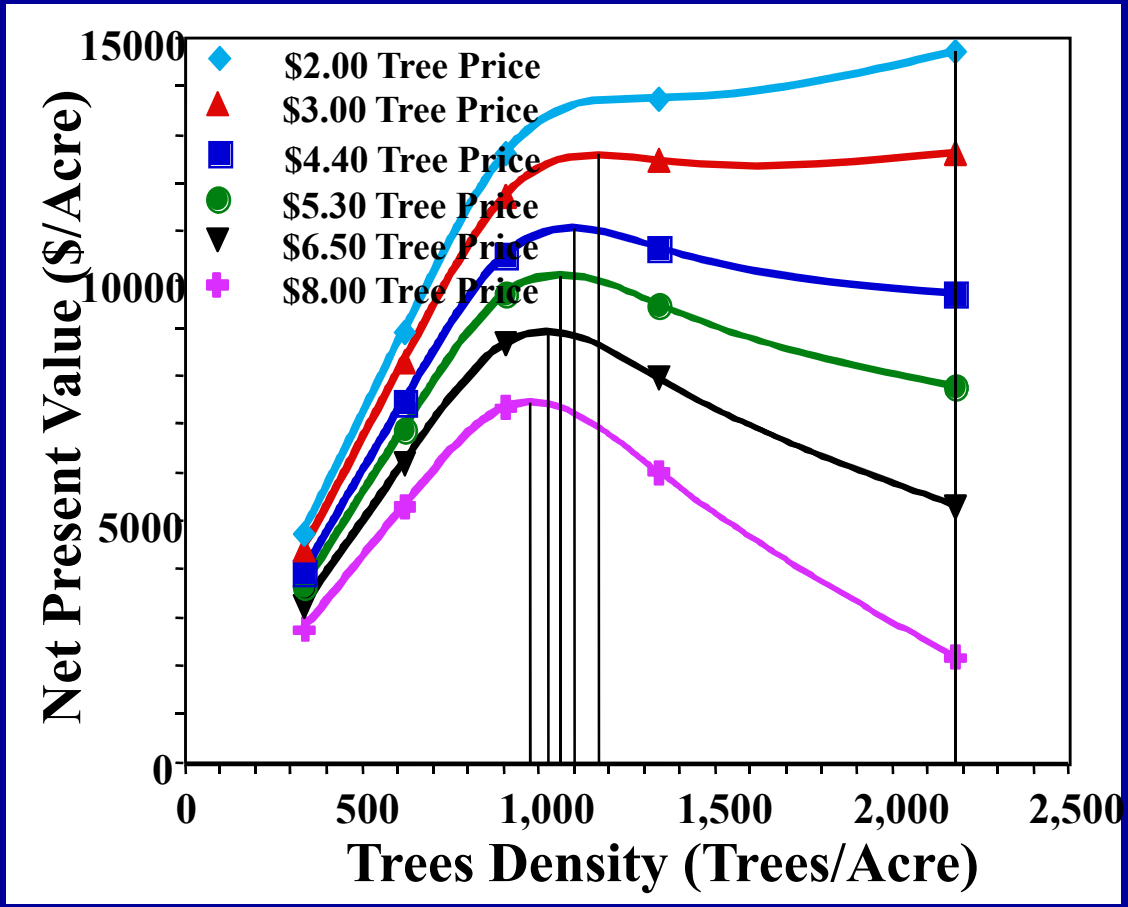


- Low tree prices ($2.00/tree) the optimum density was above 2,000 trees/acre (Super Spindle).

- 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.

Effect of Tree Price



- 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.

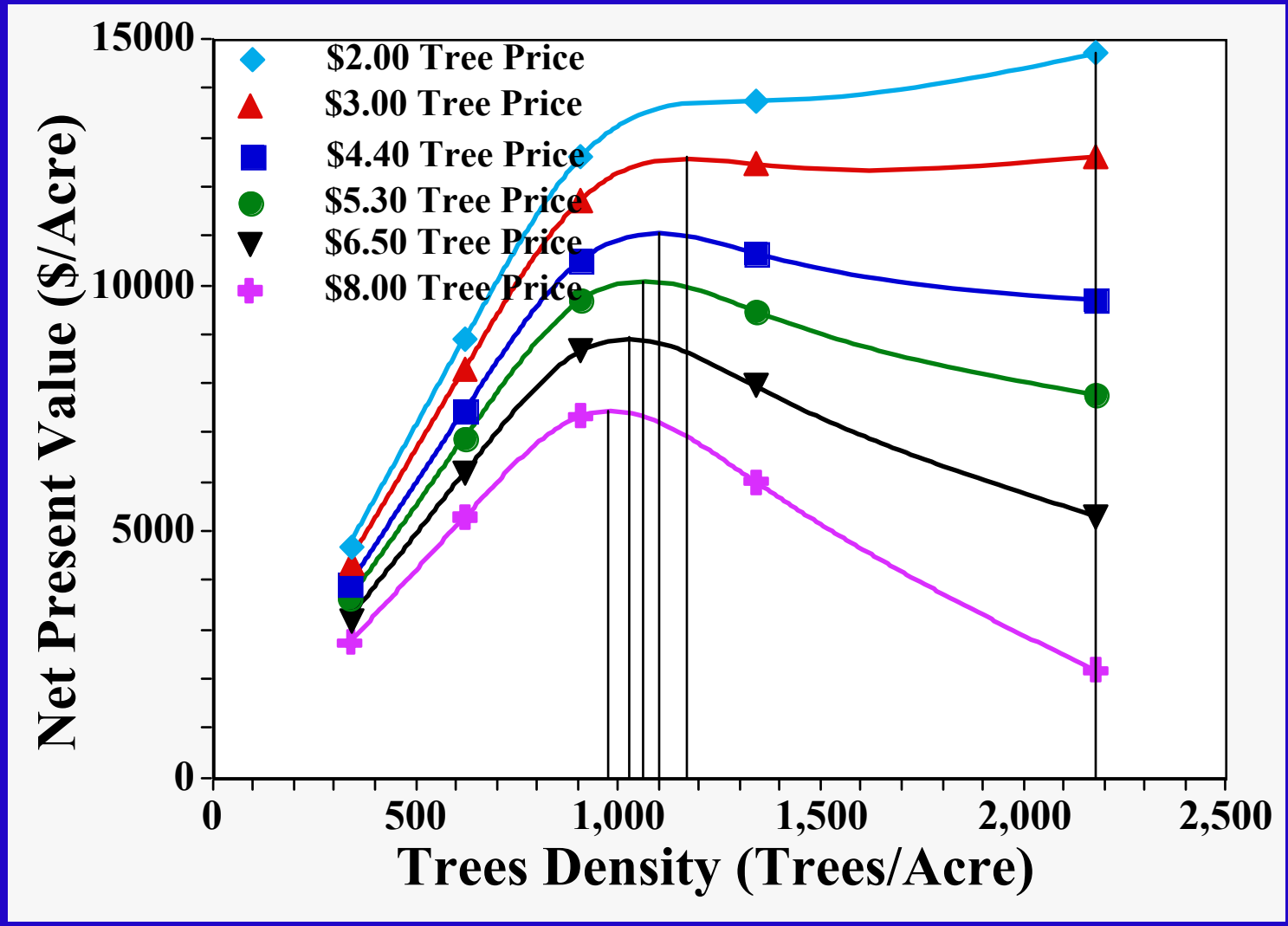
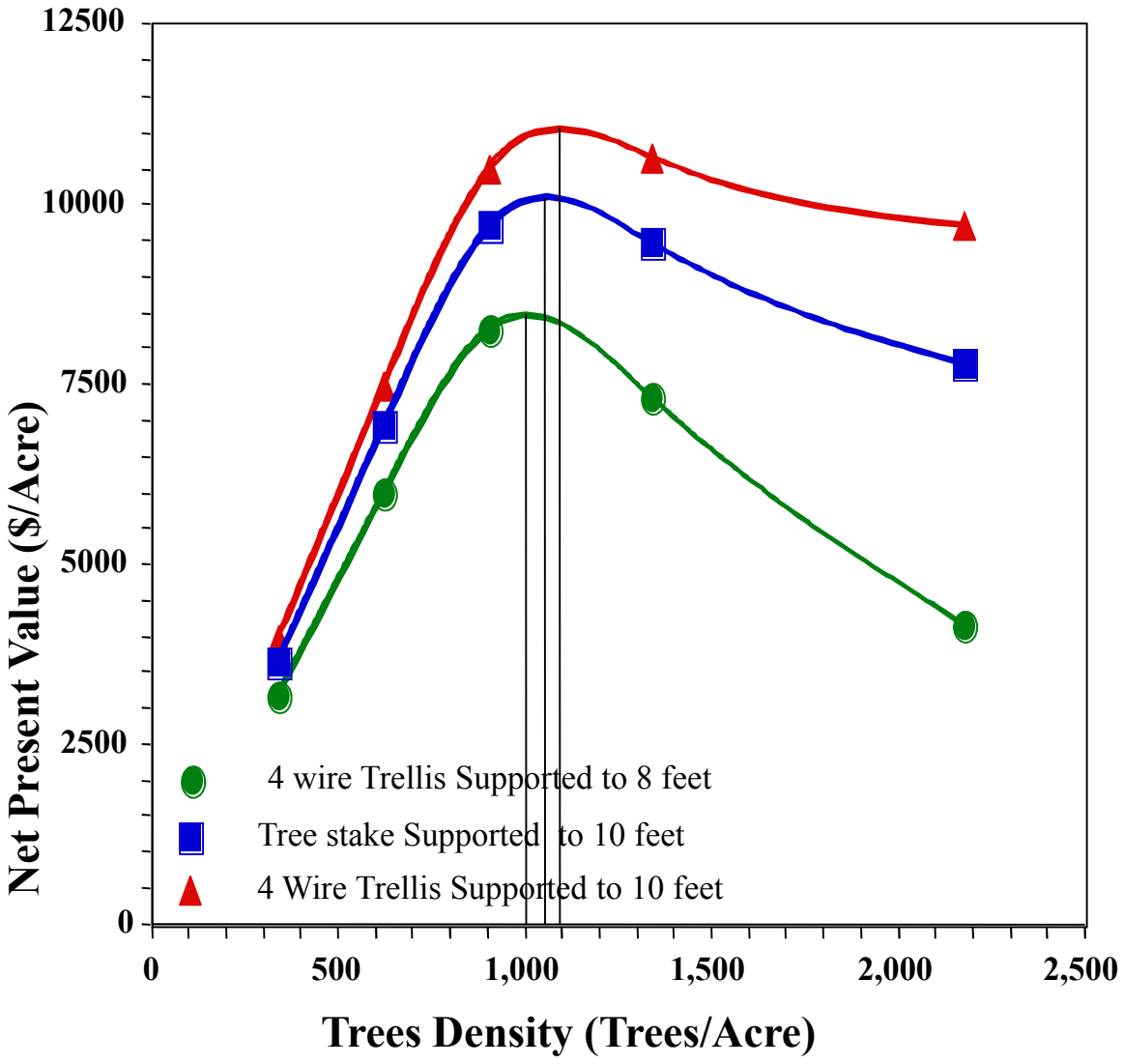


Figure 9. Effect of tree price on profitability (Net Present Value after 20 years) of 5 orchard systems with different tree densities.

Planting and Support System



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 (year18-20) 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, 2nd 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
  - 1st 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.


Shelf Cut


Typical Response

Top Management

Leader Replacement